APPENDIX H.1

APP FACILITIES DISCHARGE CALCULATION AND BADCT EVALUATION

Technical Memorandum

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Date:	September 1, 2022	**CC:**	File
Ref:	APP Facilities Discharge Calculations and BADCT Evaluation		

1 Introduction and Objectives

Wood Environment and Infrastructure Solutions, Inc. (Wood) prepared this technical memorandum for Rosemont Copper Company (Rosemont) to present discharge, leakage rate, and alert level calculations for the Rosemont Copper World Project (Project) facilities in support of an Aquifer Protection Permit (APP) Application. The facility design and this evaluation are in accordance with requirements identified in Arizona Mining Best Available Demonstrated Control Technology (BADCT) Guidance Manual (Arizona Department of Environmental Quality (ADEQ), 2004). Discharge calculations for the following facilities are addressed by this technical memorandum: Tailing Storage Facilities (TSFs) 1 and 2, Heap Leach Pad (HLP), Primary Settling Pond (PSP), Pregnant Leach Solution Pond (PLS Pond), Raffinate Pond, and the Process Plant Reclaim Pond (Reclaim Pond). The Processing Area Stormwater Pond, and the North and South Heap Leach Facility (HLF) stormwater ponds are also evaluated.

ADEQ requires using BADCT to minimize the potential effects on underlying groundwater as a prerequisite to obtaining an APP for the planned TSFs, HLF, process solution ponds, and stormwater ponds. BADCT is to be applied throughout the entire facility life cycle including design, construction, operation, and closure. The engineering analyses described herein were performed in general accordance with requirements for the APP, Arizona Revised Statute (A.R.S.) 49-243.B.1 and followed the individual or prescriptive BADCT criteria.

The site location and individual mine facilities addressed in this memorandum are shown on Figure 1.

2 BADCT Criteria

2.1 General

The operation of mining facilities that may affect groundwater in the State of Arizona requires that those facilities be permitted under the promulgated APP program. An APP issued by ADEQ must be available prior to operation of a subject facility. The construction and operation of facilities are required to follow the BADCT guidelines for a specific mining facility type and site in accordance with A.R.S 49-243.B.1.

This statute requires permitted facilities to utilize BADCT in their design, construction and operation while considering various factors depending on whether the facility is new or existing.

The requirements of BADCT are met, according to A.R.S. 49-243.B.1, if it is demonstrated:

That the facility will be so designed, constructed, and operated as to ensure the greatest degree of discharge reduction achievable through application of the BADCT, processes, operating methods or other alternatives, including, where practicable, a technology permitting no discharge of pollutants. In determining BADCT, processes, operating methods or other alternatives, the director shall take into account site-specific hydrologic and geologic characteristics and other environmental factors, the opportunity for water conservation or augmentation and economic impacts of the use of alternative technologies, processes or operating methods on an industry-wide basis. However, a discharge reduction to an aquifer achievable solely by means of site-specific characteristics does not, in itself, constitute compliance with this paragraph. In addition, the director shall consider the following factors for existing facilities:

a) Toxicity, concentrations and quantities of discharge likely to reach an aquifer from various types of control technologies.

b) The total costs of the application of the technology in relation to the discharge reduction to be achieved from such application.

c) The age of equipment and facilities involved.

d) The industrial and control process employed.

e) The engineering aspects of the application of various types of control techniques.

f) Process changes.

g) Non-water quality environmental impacts.

h) The extent to which water available for beneficial uses will be conserved by a particular type of control technology.

Arizona Administrative Code (A.A.C.) R18-9-A202(A)(5) requires that an application for or a major modification to an APP include a description of the BADCT to be employed at the facility. The procedures and information presented in the guidance manual are intended for use in determining the appropriate BADCT to reduce discharge.

2.2 Prescriptive and Individual BADCT Permitting

Two general approaches to demonstrate BADCT are possible:

Prescriptive BADCT: Requires evaluating and selecting a pre-determined discharge control technology as the BADCT design.

Individual BADCT: Establishes a reference design incorporating a combination of demonstrated control technologies that are appropriate for the site and then evaluating the aquifer loading potential for the reference design and alternative designs that include additional or different demonstrated control technologies. The practical design resulting in the lowest significant pollutant load to the aquifer would be selected as the BADCT design. Individual BADCT development may be based on considerations of waste characteristics, site characteristics (hydrology, hydrogeology, etc.), design measures, operational features, and closure methodology.

Individual BADCT evaluations are performed when either a prescriptive discharge control technology is not identified or an alternative to a prescriptive technology is proposed.

3 Individual BADCT Facility Discharge Calculations and Evaluation for Tailings Storage Facilities (TSFs) 1 and 2

Individual BADCT evaluations for tailings storage facilities (TSF-1 and TSF-2) are compared to the BADCT design in this section. The locations of TSFs 1 and 2 are shown on Figure 1. The TSF footprint is the area within the interior toe of the perimeter embankment. The footprint area of TSF-1 is 317 acres and of TSF-2 is 105 acres.

The discharge from the bottom of TSFs 1 and 2 was calculated for three alternative configurations of the facility bottom.

3.1 Tailings Storage Facilities (TSFs) Description and Alternative Configurations

The TSF's will have processed cyclone tailings slurry pumped to the top and along the side slopes of the impoundments for final depositional and water recycling purposes. The impounded solutions and precipitation that falls on the impoundment then either evaporate, are decanted and recycled back into the mining and extraction process, or slowly seep to the bottom of the impoundment. Liquid at the bottom of a TSF impoundment can either be removed by the underdrain collection system or percolate into the underlying soil or rock. Water that percolates from the bottom of a tailings facility has the potential to affect groundwater. The rate at which water percolates from a tailings facility depends on both the configuration of the facility and the hydrogeologic characteristics of the site.

Three alternative TSF bottom configurations are illustrated on Figure 2.

In Alternative 1, tailings at the bottom of the TSF are in direct contact with native material – soil and rock – below the footprint of the TSF. Soil is present across most of the footprint of both TSFs. Within the footprint of the TSFs, vegetation is removed, and the area is grubbed, and oversize material is removed. The soil is roller compacted to provide a smooth, firm surface, but compaction is not performed to achieve a density or hydraulic conductivity standard. Rock is left exposed in the incised drainage channels where the soil cover was naturally removed by erosion. In the existing exposed rock areas, debris is removed but no further improvements are made. Discharge from the tailings facility into the underlying materials is controlled by the hydraulic characteristics of the soil and rock immediately below the facility and the vertical hydraulic gradient.

In Alternative 2, the subgrade is prepared as in Alternative 1. A finger underdrain system is constructed to collect water that accumulates at the bottom of the tailings facility. The underdrain system consists of a network of perforated high-density polyethylene (HDPE) pipes placed directly on existing exposed bedrock in the incised drainage channels and on the prepared subgrade adjacent to the channels. The perforated pipes are wrapped with geotextile that prevents fine particles from entering – and potentially clogging – the drainage pipes. The pipe network is covered with an 18-inch-thick layer of free-draining gravel or crushed rock that serves as a drainage layer. With a finger drain configuration, the drainage pipes and associated gravel envelopes cover only part of the facility bottom, and native material – rock or prepared subgrade – is present in the remainder of the area. The spacing and configuration of the underdrain system will be designed to have at least 80 percent collection efficiency rate, using seepage modeling software as part of detailed design. Water collected by the underdrain system reports to a series of lined collection trenches, where it is removed and returned to the mine process water system. Removing water from the bottom of the tailings facility reduces the amount of water available to discharge from the facility and potentially affect groundwater. As in Alternative 1, discharge from the tailings facility into the underlying materials is controlled by the hydraulic characteristics of the soil and rock immediately below the facility and the vertical hydraulic gradient. Removal of water by the underdrain system reduces the amount of water potentially available to discharge from the bottom of the TSFs relative to the amount available in Alternative 1.

Alternative 3 is the prescriptive BADCT design (ADEQ, 2004). From top to bottom, the liner system consists of an overliner drain system, a 60-mil high-density polyethylene (HDPE) geomembrane and a compacted subgrade. The overliner drainage layer is an 18-inch-thick layer of ¾ inch minus well-draining gravel or crushed rock, with perforated, corrugated HDPE pipe wrapped with geotextile to exclude fine particles. The overliner drain extends across the entire extent of the TSFs, in contrast to the finger drain configuration in Alternative 2 and serves both to protect the geomembrane from damage and to collect liquid that drains from tailings. As in Alternative 2, the drain system reduces the amount of water that can potentially discharge from the bottom of the TSFs. The overliner drain reduces the hydraulic head acting on the geomembrane, thereby reducing discharge from the TSF.

The subgrade includes both native soil and imported soil fill placed over the exposed rock in the incised drainage channels to provide a suitable base for the geomembrane. Both the native soil and the imported fill are compacted to meet the BADCT criterion of hydraulic conductivity of 10^{-6} cm/s or less.

The hydraulic head acting on the geomembrane below the drainage layer is assumed to be 2 feet, consistent with BADCT guidance (ADEQ, 2004) that indicates a TSF drainage layer must limit the average head above a liner to an average value of 2 feet or less.

The rate at which water leaks through a geomembrane liner is controlled largely by the size and frequency of defects such as failed seams, tears, or holes; the hydraulic conductivity of the material immediately below the geomembrane; how well the geomembrane contacts the underlying material, and the hydraulic head above the geomembrane. The approach for calculating the leakage rate through defects in a geomembrane liner is described in Section 3.3.

3.2 Tailings Storage Facility Water Budget

The amount of water that discharges from the bottom of a TSF is limited by the availability of water in that TSF and the hydrogeologic characteristics of the TSF (i.e., drainage and liner systems) and the soil and rock below it. This section addresses water availability. The following section addresses hydrogeologic controls.

Water budget calculations for the entire project, including the TSFs, are provided in *Site-Wide Water Balance Memorandum* (Wood, 2022a). Excerpts from the site-side water balance calculations for TSF-1 and TSF-2 are provided in Attachment 1. These calculations were performed to support the summary-level water balance presented in Wood (2022a). The site-wide water balance assumed that an underdrain would remove approximately 98 percent of the water that seeps to the bottom of a TSF. For this memorandum, the finger underdrain is assumed to remove 80 percent of the seepage. Therefore, the values in the *Seepage Collected by Underdrain* and *Seepage Potentially Discharging to the Environment* columns in Attachment 1 differ from the corresponding values in the site-wide water balance.

The tailings and associated water discharged in the TSFs vary throughout the operating life of the mine, and therefore the amount of water that could potentially discharge from the TSFs and affect the environment also varies over time (Tables A1-1 through A1-4). The potential discharge is greatest in mine operating years 11 through 15 at TSF-1, and in year 15 at TSF-2. Table 3-1 summarizes the maximum amount of water that could potentially discharge from TSFs 1 and 2 in Alternatives 1 and 2. The potential discharge is less in Alternatives 2 and 3 than in Alternative 1 because the underdrain systems in Alternatives 2 and 3 remove a portion of water from the bottom of the TSFs. The finger underdrain in alternative 2 and the overliner drain in Alternative 3 are both assumed here to remove 80 percent of the available seepage at the bottom of the TSF. As shown below in Section 3.4, the line in Alternative 3 further restricts discharge from the TSFs and the actual discharge differs between Alternative 2 and 3.

Table 3-1: Potential Discharge to the Environment from Tailings Storage Facilities

Facility	Alternative	Mine Operating Year of Maximum Potential Discharge[1]	Maximum Potential Discharge[2] (gallons per minute)
TSF-1	1 – No liner, no underdrain	11 - 15	759
	2 – No liner, finger underdrain		152
	3 – Single geomembrane liner, blanket underdrain[3]		152
TSF-2	1 – No liner, no underdrain	15	377
	2 – No liner, finger underdrain		75
	3 – Single geomembrane liner, blanket underdrain		75

Notes
1. See Tables A1-1 through A1-4
2. See Tables A1-1 and A1-3 for Alternative 1, and Tables A1-2 and A1-4 for Alternatives 2 and 3
3. Drainage system assumed to remove 80 percent of the available seepage at the bottom of the TSF for both Alternatives 2 and 3

3.3 Discharge Calculation Approach

The discharge from the bottom of each tailings facility was calculated using a two-step process. First, the discharge controlled either by flow into soil and rock below the TSF (Alternatives 1 and 2) or by leakage through a geomembrane liner (Alternative 3) was calculated for each TSF. Those calculated discharges are not constrained by water availability. Second, the discharge values were compared to the maximum potential discharge (Table 3-1). The discharge from the bottom of a TSF is the smaller of the two values.

3.3.1 Alternatives 1 (Unlined) and 2 (Unlined with Underdrain System)

The discharge from the bottom of an unlined TSF is controlled by the rate of flow through the soil and rock units that underlie the facilities, and the availability of water.

Potential flow from the bottom of a facility controlled by the hydraulic properties of soil and rock beneath the facility was calculated using the Darcy Equation:

$$Q = KiA$$

Where Q is discharge (with units of volume per unit time)

K is hydraulic conductivity (with units of length per unit time)

i is the vertical hydraulic gradient (unitless), which is dh/dz, where h is hydraulic head (length), z is elevation (length), and d/d is the differential operator

A is cross sectional area through which flow occurs (with units of area).

The values for parameters are as follows.

- Hydraulic conductivity (K)
  - In Alternative 1, soil and rock units with different values of hydraulic conductivity are present in the footprint of the TSFs. The Darcy flow is calculated for each soil or rock unit using the hydraulic conductivity and the

plan view area of that unit. The Darcy flow for a TSF is the sum of the calculated flow for each soil or rock unit. Table A2-1 provides the hydraulic conductivity and areal extent of each soil and rock unit exposed at the bottom of TSFs 1 and 2. The hydraulic conductivity values for the unconsolidated Basin Fill and Recent Alluvium are based on infiltration tests performed in exploratory test pits. Representative hydraulic conductivity values for rock types that outcrop below the facilities were selected based on experience with similar materials at other sites.

- In Alternative 2, the finger underdrain system that covers part of the TSF footprint has much higher conductivity than the underlying soil and rock units and hence does not impede downward movement of water. The Darcy flow from the bottom of the TSFs is controlled by the hydraulic conductivity of the native soil and rock units, and thus the Darcy flow in Alternative 2 is the same as in Alternative 1.

- Hydraulic Gradient (i)

  - In Alternatives 1 and 2 the vertical hydraulic gradient is assumed to be 1. This is appropriate for downward flow in partially saturated material below a TSF in which the water content profile is at a steady-state (constant in time) condition. This condition is expected to exist in the vadose zone between the bottom of a TSF and the water table of the underlying aquifer.

- Area (A)

  - The area of each soil or rock unit present below TSFs 1 and 2 is used to calculate the Darcy discharge through each unit. The sum of the discharge through each unit below TSF 1 or 2 is the Darcy discharge for the entire TSF. The TSF area used in this evaluation is the footprint bounded by the toe of the upstream (interior) perimeter embankment slope.

3.3.2 Alternative 3 (Geomembrane Liner with Overliner on Compacted Subgrade)

The discharge from the bottom of a TSF with a geomembrane liner above the underlying soil and rock is controlled by the rate at which water leaks through the geomembrane into the underlying material.

The geomembrane leakage rate was estimated using the approach described in *Evaluation of Landfill Liners* (Giroud et al., 1994). The leakage rate depends on the size and frequency of defects in the geomembrane, the thickness and hydraulic conductivity of the material immediately below the geomembrane, how well the geomembrane contacts the underlying material, and the hydraulic head above the membrane.

In accordance with guidance provided by US Environmental Protection Act (US EPA) (1989) and US EPA (1992), a 1 cm^2 defect per 4,000 m^2 of geomembrane area is assumed.

The soil and rock units below the TSFs are much thicker (tens of feet) than the expected hydraulic head (feet) above the geomembrane. Therefore, equations for a geomembrane overlying a thick low-conductivity soil underliner were used.

Good contact between the geomembrane and underlying material is assumed. The hydraulic head above the membrane is assumed to be two feet, consistent with BADCT guidance (ADEQ, 2004) that indicates the average hydraulic head on a liner with an overliner drainage system should be no more than two feet.

Based on the assumed conditions, Equations 7 (for good membrane contact) and 8 (for poor contact) from Giroud et al. (1994) can be used to estimate leakage through a geomembrane at the bottom of the TSFs. Those equations are summarized as:

$$Q = c\ a^{0.1}\ h^{0.9}\ K^{0.74}$$

Where:

- Q is the leakage rate (m^3/s) per 4,000 m^2 (based on the assumption of one defect per 4,000 m^2 in accordance with US EPA guidance)
- c is a coefficient that accounts for 'good' (0.21) or 'poor' (1.15) contact between the geomembrane and the underlying material (unitless). Good contact is assumed. C=0.21
- a is the size of the defect (m^2). A 1 cm^2 = $1x10^{-4}$ m^2 defect is assumed.
- h is hydraulic head above the membrane (m). The head above the membrane is assumed to be 0.6 m, equal to approximately 2 feet, consistent with BADCT guidance (ADEQ, 2004) that indicates a TSF drainage layer must limit the average head above a liner to an average value of 2 feet or less.
- K is the hydraulic conductivity of the material immediately below the geomembrane (m/s). Hydraulic conductivity of 10^{-8} m/s (10^{-6} cm/s) was assumed, consistent with BADCT requirements for a prepared subgrade compacted to achieve a maximum hydraulic conductivity of 10^{-6} cm/s).

The geomembrane leakage rate was calculated for one imperfection per 4,000 m^2. The total discharge to the environment from the entire TSF was calculated by multiplying the leakage rate per 4,000 m^2 by the TSF area in m^2 and dividing by 4,000. As in the Darcy flux approach used in Alternatives 1 and 2, the TSF area used in this evaluation is the footprint bounded by the toe of the upstream (interior) perimeter embankment slope.

3.4 TSF Discharge Calculation Results

Detailed calculations of the Darcy discharge from TSF -1 for Alternatives 1 and 2 are provided in Table A2-2. Table A2-3 provides the geomembrane leakage rate calculations for Alternative 3. For TSF-2, Tables A2-4 and A2-5 provide the corresponding calculations for TSF-2.

The Darcy discharge and membrane leakage rates calculated in Tables A2-2 through A2-5 assume that water is readily available, i.e., that the flow through the TSF footprint is not limited by the amount of water in the TSF. As discussed in Section 3.2, the water available in each TSF is limited. The maximum discharge from a TSF is the smaller of the maximum potential discharge (Table 3-1) and the calculated Darcy discharge (Alternatives 1 and 2), or the smaller of the maximum potential discharge and the leakage through the geomembrane (Alternative 3). These values are compared in Table 3-2. Limited water availability controls discharge from the TSFs in Alternatives 1 and 2, but not in Alternative 3.

Table 3-2: Discharge from TSF-1 and TSF-2 Constrained by Water Availability

Facility	Alternative	Maximum Potential Discharge[2] (gal/min)	Darcy Discharge with Unlimited Water Availability[3] (gal/min)	Membrane Leakage with Unlimited Water Availability[4] (gal/min)	Discharge from Facility[5] (gal/min)	Discharge from Facility[5] (gal/day)
TSF-1	1 – Unlined, no underdrain	759	3,914,009	—	759	1,092,672
	2 - Unlined, finger underdrain	152	3,914,009	—	152	218,534
	3- Geomembrane liner on compacted subgrade and overliner drain	152	—	0.32	0.32	465
TSF-2	1 – Unlined, no underdrain	377	1,406,837	—	377	542,880
	2 - Unlined, finger underdrain	75	1,406,837	—	75	108,576
	3- Geomembrane on compacted subgrade and overliner drain	75	—	0.11	0.11	154

Notes

1. Discharge refers to drain-down water that percolates into materials below a TSF and has the potential to reach groundwater.
2. See Table 3-1.
3. Alternatives 1 and 2. Tables A2-2 and A2-4.
4. Alternative 3. Table A2-3 and A2-5.
5. The smaller of maximum potential discharge and discharge or leakage with unlimited water availability.

In Alternatives 1 and 2, the discharge from the bottom of TSF-1 and TSF-2 is constrained by the availability of water, not by the hydrogeologic characteristics of the TSFs or the soil and rock below them. The underdrain in Alternative 2 reduces the available water, and therefore the discharge is less in Alternative 2 than in Alternative 1.

In Alternative 3, discharge from the bottom of TSF-1 and TSF-2 is not constrained by the availability of water, but instead is limited by the rate of leakage through the geomembrane installed above a compacted subgrade that meets BADCT compaction and hydraulic conductivity requirements.

3.5 Summary of TSF Results

Table 3-3 compares the discharge between alternatives. Alternative 3 is the BADCT design.

At TSFs 1 and 2, discharge from an unlined facility is controlled by the limited availability of water. The underdrain system in Alternative 2 reduces discharge from the TSFs relative to the unlined TSF (Alternative 1). The effectiveness of the underdrain was assumed to be 80 percent. Adding a geomembrane liner and a compacted subgrade consistent with BADCT criteria (Alternative 3) reduces discharge by over 99 percent relative to Alternative 2.

RCC-CW003733

Table 3-3: Comparison of Individual Discharge Control Technologies to BADCT Design

Facility	Alternative	Discharge from Facility (gal/min)	Discharge from Facility (gal/day)
TSF-1	1 - Unlined – no underdrain	759	1,095,672
	2 – Unlined, finger underdrain -	159	218,534
	3- Geomembrane liner on compacted subgrade and overliner drain (BADCT)	0.32	465
TSF-2	1 - Unlined – no underdrain	377	542,880
	2 – Unlined, finger underdrain	75	108,576
	3- Geomembrane liner on compacted subgrade and overliner drain (BADCT)	0.11	154

3.6 Comparison to Seepage Modeling Results

A separate evaluation of the discharge rate from TSFs 1 and 2 is presented in *Rosemont Copper World Project – TSF 1 and 2 Seepage Analysis Memorandum* (Wood, 2022b), i.e., the Seepage Memo.

The evaluations presented here and in the Seepage Memo are not directly comparable for the following reasons.

1. The evaluations had different objectives. The objective of this evaluation was to determine the effect of various TSF bottom configurations (e.g., underdrain, liner) on discharge from the TSF into the underlying material. The objective of the Seepage Memo was to quantify the flowrate of deep percolation that could potentially affect groundwater for a single TSF configuration.
2. The evaluations focused on different parts of the flow system. This evaluation focused on quantifying the flowrate from a TSF with multiple bottom configurations but did not consider movement of water after it percolated out of a TSF. The Seepage Memo evaluated a single TSF configuration and considered flow in the soil and rock units below the TSFs. The focus was on quantifying the flowrate of water removed by seepage collection trenches that intercept water in alluvial soil below the TSFs and quantifying the flowrate of the remaining water into rock units below the alluvial soil. The water that flows into the rock units may potentially affect deeper groundwater.
3. Different calculation approaches were used. This evaluation calculated flowrates using empirical solutions appropriate for a given TSF bottom configuration. The Seepage Memo used a two-dimensional computer model to simulate flow and quantify flowrates at various locations in the materials in and below the TSF.

4 Prescriptive BADCT Facility Discharge Calculation and Evaluation

The prescriptive BADCT design for the HLP, process solution ponds, and stormwater ponds is compared to an alternative design.

4.1 Heap Leach Pad (HLP)

The rate of discharge from the bottom of the HLP was estimated for two configurations of the bottom.

4.1.1 HLP Description and Configurations

Run of mine and/or crushed oxide ore is placed on the HLP. Acidic leaching solution is uniformly distributed over the top and side slopes of the ore stockpile to leach copper from the ore material. The solution percolates through the stockpiled material, reacts with the ore, and generates a copper-bearing PLS. The PLS accumulates at the base of the leach pad where it flows laterally to a central collection system that reports to the PLS Pond. Copper is extracted from the PLS solution in a separate solvent extraction/electrowinning process, leaving a barren raffinate. The barren raffinate is amended with acid and then reused in the leaching process.

If PLS were to leak from the bottom of the HLP, it would have the potential to affect groundwater. The rate at which liquid percolates from the bottom of the HLP depends on both the configuration of the facility and the hydrogeologic characteristics of the site.

Two alternative HLP configurations were evaluated, as illustrated in Figure 3.

In Alternative 1 (the BADCT design), an 80-mil textured linear low density polyethylene geomembrane is installed above a compacted subgrade compacted to achieve a maximum hydraulic conductivity of 10^{-6} cm/s. The compacted subgrade acts as a low hydraulic conductivity element that restricts flow through imperfections in a geomembrane. The compacted subgrade is extended to cover rock in natural drainage channels. An overliner drainage system above the geomembrane collects PLS and reduces hydraulic head on the geomembrane. The liner system is a low hydraulic conductivity element that restricts downward movement of PLS and reduces the discharge of liquid from the bottom of the HLP.

Alternative 2 modifies the Alternative 1 liner by adding a geosynthetic clay liner (GCL) below the geomembrane. The soil below the GCL is compacted to provide a smooth, stable subgrade for the GCL, but it is not compacted to achieve a hydraulic conductivity criterion; instead, the GCL acts as the low hydraulic conductivity element below the geomembrane.

The rate at which water leaks through a geomembrane liner is controlled largely by the size and frequency of defects such as failed seams, tears, or holes, the hydraulic conductivity of the material immediately below the membrane, how well the membrane contacts the underlying material, and the hydraulic head above the membrane. The approach for calculating the leakage rate through defects in the geomembrane is described in Section 4.1.3. The area of the HLP footprint is 336 acres.

4.1.2 Heap Leach Pad (HLP) Water Budget

The HLP is expected to be used during operating years 1 through 9, and then closed. During the operating period, acidic leaching solution is applied at a rate of 3,000 gallons per minute. The evaporative loss is 45 gpm. The remaining 2,956 gpm of PLS is recovered from the bottom of the ore pile by the overliner drainage system.

4.1.3 HLP Discharge Calculation Approach

The discharge from the HLP was estimated using a membrane leakage approach for both Alternatives 1 and 2. The estimated discharge values are compared to the HLP net inflow. The discharge from the bottom of the HLP is the smaller of the two.

The following assumptions were utilized for calculating the discharge from the HLP.

- 1-D steady-state seepage.
- All alternatives have a one-foot prepared and compacted soil base. In Alternative 1 the subgrade is compacted to achieve hydraulic conductivity of 10^{-6} cm/s or less as required by BADCT. In Alternative 2 the soil is compacted sufficiently to provide a suitable base for a geomembrane and GCL, but not to meet a hydraulic conductivity criterion.
- Constant head of 2 feet over the geomembrane due to leaching solution application and accumulation of PLS at the base of the stacked ore, and removal of PLS by an overliner drainage system, as prescribed in the BADCT Guidance Manual for a geomembrane with an overliner drainage system.
- The geomembrane liner has a one square centimeter (cm^2) defect per 4,000 square meters (m^2) of lined area per EPA guidance (US EPA, 1989; 1992).

- Contact between geomembrane liner and soil underliner is 'good'. Good contact assumes that there are minimal wrinkles in the geomembrane while being installed and/or the liner is placed on compacted and stable soil base that has been well compacted and appears smooth.

Alternative 1 Geomembrane Liner on Compacted Subgrade, with Overliner Drainage System

The discharge from the bottom of an HLP with a geomembrane liner above the underlying soil and rock is controlled by the rate at which water leaks thorough the geomembrane into the underlying material.

The leakage through the geomembrane liner was calculated using the approach described above for TSF Alternative 3 for a geomembrane above a thick soil underliner. The hydraulic conductivity of the material below the geomembrane is assumed to be 10^{-6} cm/s, consistent with BADCT requirements for a compacted subgrade. A 2-foot hydraulic head above the geomembrane was used in calculations, in accordance with BADCT guidance for the average depth of ponded water at the bottom of a HLP.

Alternative 2 Geomembrane Liner on GCL Underliner, with Overliner Drainage System

As in Alternative 1, discharge from the bottom of an HLP with a geomembrane – GCL composite liner is controlled by the rate at which water leaks thorough the geomembrane into the underlying GCL. The approach described for HLP Alternative 1 was modified slightly to account for the difference in the material immediately below the geomembrane: a thick soil underliner in Alternative 1 and a thin GCL in Alternative 2. A GCL is thin – typically ¼ inch – relative to the depth of ponded water above the liner – typically feet. For this situation, Equation 9 from Giroud et al. (1994) can be used to estimate leakage through a composite geomembrane-GCL liner:

$$Q = c\ i_{avg}\ a^{0.1}\ h^{0.9}\ K^{0.74}$$

where i_{avg} is a dimensionless coefficient whose value depends on the ratio of head (h) above the geomembrane to the thickness (D) of the low hydraulic conductivity element below the membrane. The relationship between i_{avg} and h/D is provided in Figure 1 of Giroud et al. (1994). For this case, h=0.6 m (2 feet), D=0.006 m (¼ inch), and h/D = 10^2. The corresponding value of i_{avg} is 8. The other terms were defined previously in Section 3.3.2.

4.1.4 Discharge Calculation Results

Detailed calculations of the rate of leakage through a membrane liner (Alternatives 1 and 2) are provided in Tables A3-1 and A3-2.

The membrane leakage rates calculated in Tables A3-1 and A3-2 assume that water is readily available, i.e., that the flow through the bottom of the HLP footprint is not limited by the net inflow into the heap. Net inflow is greater than the membrane leakage rates, and therefore discharge from the heap is controlled by the membrane leakage rates in Alternatives 1 and 2. The net inflow and calculated discharge or leakage rates for the HLP are summarized in Table 4-1. The leakage rate for the BADCT design (Alternative 1) is greater that for the design with a GCL (Alternative 2) instead of a compacted subgrade. Using a GCL instead of a compacted subgrade reduces the leakage rate by approximately 84 percent.

Table 4-1: Leakage from the HLP with Two Alternative Liner Configurations

Facility	Alternative	Maximum Potential Discharge (gal/min)	Membrane Leakage with Unlimited Water Availability (gal/min)	Discharge from Facility (gal/min)	Discharge from Facility (gal/day)
HLP	1- Geomembrane liner on thick soil underliner	2,956	0.34	0.34	492
	2 - Geomembrane liner on thin GCL underliner	2,956	0.05	0.05	78

The calculated discharge values in Table 4-1 are likely greater than what the actual discharge rates will be. This is primarily because the HLP will be constructed in stages. PLS could discharge into the subsurface only below the portion of the HLP that is in service. Therefore, the values in Table 4-1 that assume the entire footprint of the HLP is in service and overestimate the actual discharge.

4.2 Process Solution Ponds

The process solution ponds are:

- PSP
- PLS Pond
- Raffinate Pond
- Reclaim Pond

4.2.1 Description

The process solution ponds have dual liner systems. Two alternative configurations are evaluated. Figure 4 illustrates the liner configurations for process solution ponds.

Alternative 1 is the prescriptive BADCT design. The liner system for all process solution ponds incorporates a geomembrane double liner and a leak collection and removal system (LCRS). The composite liner has a primary (upper) and secondary (lower) geomembrane. Both membranes are ultraviolet (UV) light resistant, 60-mil HDPE material. A geonet between the two membranes acts as an LCRS that collects water that leaks through the primary liner and drains it to a collection sump. Liquid drains from the geonet by gravity flow to a collection sump adjacent to the pond. This design minimizes the head on the secondary liner by maintaining a freely drained condition between the primary and secondary liner. The 60-mil secondary geomembrane is underlain by a compacted subgrade. All components of the composite liner system are in good contact with each other and the underlying material.

Alternative 2 increases the thickness of the primary and secondary HDPE geomembranes to 80 mils. The compacted subgrade below the secondary geomembrane used in Alternative 1 is replaced with a GCL over a prepared subgrade. All components of the composite liner system are in good contact with each other and the underlying material.

The PSP and PLS ponds have reservoir areas of approximately 5.1 and 3.2 acres, respectively. The Raffinate and Reclaim ponds each have a reservoir area of approximately 1.5 acres.

4.2.2 Discharge Calculation Approach

Discharge from a pond with a membrane liner system is equal to the rate of leakage through the liner, which is controlled by the hydraulic head above the liner, the size and frequency of defects (e.g., holes, imperfect seams, tears) in the liner, the hydraulic conductivity of the material immediately below the membrane, and the quality of the contact between the membrane and the underlying material. In a dual-membrane liner with a LCRS between the primary and secondary membranes, leakage through the primary (upper) membrane is removed by the LCRS. and only leakage through the secondary (lower) membrane reports to the environment.

The approach described by Giroud et al. (1994) is used here to estimate leakage through a membrane liner. The applicable equation is

$$Q = c i_{avg} a^{0.1} h^{0.9} K^{0.74}$$

Where:

Q = discharge through liner (m^3/s) per 4,000 m^2 of membrane

c = contact constant (1.15 for "poor" and 0.21 for "good" conditions)

i_{avg} = a dimensionless coefficient determined from Figure 1 in Giroud et al. (1994)

a = area of defect (m^2)

h = head on liner (m)

K = hydraulic conductivity of underliner (m/s)

The assumptions used for calculating the discharge from the bottom of ponds are as follows.

- Good contact between the secondary liner and the GCL below it. c=0.21.
- The hydraulic head acting on the primary geomembrane, i.e., the depth of water in the pond, affects the rate at which water leaks through the primary geomembrane. Most of that leakage is removed by the LCRS. Only water that subsequently leaks through imperfections in the secondary geomembrane reports to the environment.
- The geonet between the primary and secondary geomembranes acts as a LCRS that removes water that leaks through the primary membrane. That leakage is conveyed to a sump outside the pond, where it is removed for further management. The rate at which water leaks through defects in the primary geomembrane does not control the discharge rate from the bottom of a pond into the environment below the pond. Instead, only leakage through defects in the secondary geomembrane results in discharge from the pond bottom that reports to the environment. Hence, the size and frequency of defects in the secondary geomembrane, the hydraulic head above the secondary geomembrane, the hydraulic conductivity of the material below the secondary geomembrane, and the contact condition between the geomembrane and the underlying material control the rate of leakage through the composite liner system from the pond bottom. The geonet LCRS is maintained in a free-draining condition. The hydraulic head (h) on the secondary membrane is the thickness of the geonet, ¼ inch = 0.02 feet = 0.006 m. This hydraulic head value is two times the 0.01-foot value used by Giroud and Bonaparte (1989a) for the head on the lower geomembrane below a synthetic drainage layer between two geomembranes. The value used here is more conservative than the value used in *Leakage Through Liners Constructed with Geomembranes – Part II. Composite Liners* (Giroud and Bonaparte, 1989a) and would result in a larger calculated leakage rate.
- I_{avg} is determined from Figure 1 of Giroud et al. (1994) based on the ratio of hydraulic head (h) to thickness (D) of the low hydraulic conductivity material below the geomembrane, in this case the GCL.

  - h = ¼ inch = 0.006 m
  - D = ¼ inch = 0.006 m
  - h/D = 1

  - From Giroud et al., (1994), $i_{avg} = 1$

- Defects in the secondary liner are assumed to have an area of 1 cm^2 (10^{-4} m^2). a = 10^{-4} m^2.
- K is the hydraulic conductivity of the material immediately below the defect in the membrane. In Alternative 1, the compacted subgrade has hydraulic conductivity of 1 x 10^{-6} cm/s (10^{-8} m/s), consistent with BADCT requirements. In Alternative 2, the GCL has hydraulic conductivity of 5 x 10^{-11} m/s based on manufacturer's data (Layfield Group, 2022).
- EPA guidance recommends assuming one 1 cm^2 membrane defect per 4,000 m^2, which is approximately one defect per acre (1 acre = 4,047 m^2). The Giroud et al. (1994) equations calculate membrane leakage rate per 4,000 m^2 of membrane. The leakage rate for an entire facility is proportional to the facility area divided by 4,000 m^2.

4.2.3 Discharge Calculation Results

Calculations of leakage from process solution ponds with Alternative 1 and 2 liner configurations and a 1 cm^2 imperfection per 4,000 m^2 are provided in Table A4-1. Calculated leakage rates are summarized in Table 4-2. For all process solution ponds, the leakage rate for the BADCT design (Alternative 1) is greater than for the design with a GCL (Alternative 2) instead of a compacted subgrade. Using a GCL instead of a compacted subgrade reduces the leakage rate by approximately 98 percent.

Table 4-2: Discharge from Bottom of Process Solution Ponds with Two Alternative Liner Configurations

Pond	Alternative[1,2]	Area[3]		Hydraulic Conductivity of Underliner[4] K	Leakage per 4,000 m^2 Q_{4000}	Leakage Through Pond Area Q_{pond}		
		(acres)	(m^2)	(m/s)	(m^3/s)	(m^3/s)	(gal/ day)	(gal/ year)
Primary Settling Pond	1	5.1	20,450	1.0E-8	1.0E-9	5.1E-09	0.12	43
	2			5.0 E-11	2.0 E-11	1.0 E-10	0.0023	0.85
Pregnant Leach Solution Pond	1	3.2	12,960	1.0E-8	3.3E-09	3.3E-09	0.074	27
	2			5.0 E-11	2.0 E-11	6.5E-11	0.0015	0.54
Raffinate Pond	1	1.5	6,079	1.0E-8	1.0E-09	1.5E-09	0.035	13
	2			5.0 E-11	2.0 E-11	3.0E-11	0.0007	0.25
Reclaim Pond	1	1.5	5,992	1.0E-8	1.5E-09	1.5E-09	0.034	13
	2			5.0 E-11	2.0 E-11	3.0E-11	0.0007	0.25

Notes
1. Alternative 1: dual geomembrane and geonet LCRS liner system on compacted subgrade.
2. Alternative 2: dual geomembrane and geonet LCRS liner system on GCL and prepared subgrade
3. Area within the crest of the interior slope of perimeter embankment
4. Alternative 1: Prepared subgrade. Alternative 2: GCL

4.3 Non-Stormwater Water Ponds

The non-stormwater ponds are:

- Process Area Stormwater Pond
- HLF North Stormwater Pond
- HLF South Stormwater Pond.

4.3.1 Descriptions/Input

The non-stormwater ponds are used to manage contact stormwater runoff from different portions of the site. The water in these ponds is expected to have much lower solute concentrations than the liquids managed in process solution ponds, and the stormwater ponds are expected to contain water only occasionally and for short durations, in contrast to the frequent or continuous basis for process solution ponds. These differences are the basis for using a different liner system for the stormwater ponds.

Two alternative liner designs were evaluated, as illustrated in Figure 4.

Alternative 1 is the prescriptive BADCT design liner system for the stormwater ponds. It consists of a single 60-mil HDPE geomembrane liner in direct contact with a compacted subgrade.

Alternative 2 consists of a single 80-mil HDPE geomembrane, a GCL underliner, and a prepared subgrade.

The Process Area Stormwater Pond has an area of 1.5 acres. The HLF North and South stormwater ponds each have an area of 3.0 acres.

4.3.2 Discharge Calculation Approach

The discharge from the bottom of each non-stormwater pond was calculated using a membrane leakage approach. Each stormwater pond is equipped with a single geomembrane in direct contact with low permeability material below. Leakage through the liner system is controlled by the rate at which water leaks through the geomembrane into the underlying soil.

Like the process water ponds (Section 4.2), the material that immediately underlies the geomembrane (a compacted subgrade in Alternative 1 and a GCL in Alternative 2) restricts flow through defects in the membrane. In contrast to the process water pond liner systems that have a LCRS above the secondary geomembrane, there is neither a LCRS nor a secondary geomembrane in the stormwater pond liner systems. Hence, the hydraulic head acting on the single geomembrane of the stormwater pond liners is the maximum pond depth, which is much larger than that acting on the secondary liner of the process water ponds liners. This approach assumes that the stormwater ponds are always completely full. In contrast, stormwater ponds are expected to contain water periodically after storm events, and to rarely be full. Therefore. the leakage rates calculated here are greater than the rates that will actually occur.

As for the HLP and the process water ponds, the approach described by Giroud et al. (1994) and explained in Sections 4.1.3 and 4.2.2 is used here to estimate leakage through a membrane liner. The applicable equation is

$$Q = ci_{avg}a^{0.1}h^{0.9}K^{0.74}$$

The terms in this expression were defined in Sections 4.1.3 and 4.2.2.

The parameter values are as follows.

- Good contact between the geomembrane and the GCL: c = 0.21
- I_{avg} depends on the ratio of hydraulic head (h) to the thickness (D) of the low-conductivity layer below the defect in the geomembrane
  - Hydraulic head (h) is the depth of ponded water, 22 feet (6.7 m), which is the depth from the embankment crest minus 2 feet of freeboard
  - For Alternative 1
    - Thickness of the prepared, compacted soil base (d) = 6 inches (0.15 m)
    - h/d = 6.7 m / 0.15 m = 45

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  - From Giroud et al. (1994) Figure 1, i_{avg} = 4
- For Alternative 2
  - The thickness of the GCL is 0.006 m
  - h/d = 6.7 m / 0.006 m = 1,118
  - From Giroud et al. (1994) Figure 1, i_{avg} =50

- 1 square centimeter defect size: a = 10^{-4} m^2
- K is the hydraulic conductivity of the material immediately below the defect in the membrane. In Alternative 1, the compacted subgrade has hydraulic conductivity of 1 x 10^{-6} cm/s (10^{-8} m/s), consistent with BADCT requirements. In Alternative 2, the GCL has hydraulic conductivity of 5 x 10^{-11} m/s based on manufacturer's data (Layfield Group, 2022)
- EPA guidance recommends assuming one 1 cm^2 membrane defect per 4,000 m^2, which is approximately one defect per acre (1 acre = 4,047 m^2). The leakage rate for an entire facility is proportional to the facility area divided by 4,000 m^2

4.3.3 Discharge Calculation Results

Calculations of the leakage through stormwater ponds with Alternative 1 and 2 liner configurations and a 1 cm^2 imperfection per 4,000 m^2 are provided in Table A4-2. Calculated leakage rates are summarized in Table 4-3. For all stormwater ponds, the leakage rate for the BADCT design (Alternative 1) is greater than for the design with a GCL (Alternative 2) instead of a compacted subgrade below the geomembrane. Using a GCL instead of a compacted subgrade reduces the leakage rate by approximately 75 percent.

Table 4-3: Discharge from Bottom of Stormwater Ponds with Two Alternative Liner Systems

Pond	Alternative[1,2]	Area[3]		Hydraulic Conductivity of Underliner[4] K	Leakage per 4,000 m^2 Q_{4000}	Leakage Through Pond Area Q_{pond}		
		(acres)	(m^2)	(m/s)	(m^3/s)	(m^3/s)	(gal/day)	(gal/year)
Process Area Stormwater Pond	1	1.5	6,044	1.0 E-8	2.2E-06	3.4E-06	77	28,100
	2			5.0E-11	5.5E-07	8.3E-07	19	7,000
HLF North Stormwater Pond	1	3.0	12,319	1.0 E-8	2.2E-06	6.9E-06	157	57,200
	2			5.0E-11	5.5E-07	1.7E-06	39	14,200
HLF South Stormwater Pond	1	3.0	12,319	1.0 E-8	2.2E-06	6.9E-06	157	57,200
	2			5.0E-11	5.5E-07	1.7E-06	39	14,200

Notes
1. Alternative 1: single geomembrane liner on compacted subgrade.
2. Alternative 2: single geomembrane liner on GCL and prepared subgrade.
3. Area within the crest of the interior slope of perimeter embankment.
4. Alternative 1: Prepared subgrade. Alternative 2: GCL.

5 Summary of Leakage Rate Calculations

For the TSFs, both control technologies evaluated – an underdrain system (Alternative 2) and a single membrane liner system (Alternative 3) - substantially reduce discharge from the TSF footprint relative to a TSF with neither an underdrain nor a liner (Alternative 1). For the evaluation presented here, the underdrain systems in TSF-1 and TSF-2 were assumed to capture 80 percent of the net inflow and therefore reduce discharge from the bottom of each TSF by 80 percent. Seepage modeling conducted during detailed design will be used to confirm that the underdrain system will be at least 80 percent effective. An overliner drain and single geomembrane liner on a compacted subgrade reduces discharge by over 99 percent relative to a TSF with a finger drain but no liner or subgrade compacted to BADCT criteria.

For the HLP, using a geomembrane and GCL over a prepared subgrade reduces the leakage rate by approximately 84 percent relative to the BADCT design with a geomembrane over a low-permeability compacted subgrade.

For the process solution ponds, using a dual geomembrane liner with a geonet LCRS and a GCL above a prepared subgrade reduces the leakage rate by approximately 98 percent relative to the BADCT design with the same geomembrane and LCRS system above a low-permeability compacted subgrade.

For the stormwater ponds, using a single geomembrane liner and a GCL above a prepared subgrade reduces the leakage rate by approximately 75 percent relative to the BADCT design with a geomembrane liner above a compacted subgrade.

6 Leakage Rate Alert Levels for Process Solution Ponds

The preceding sections evaluated the effect of the bottom configuration (drainage systems and liners) on leakage rates from TSFs, the HLP, and ponds into the environment below those facilities. The configurations evaluated included double liner and LCRS systems for process solution ponds, and no liner or single liner systems for the other facilities. For the process solution ponds, the calculations focused on the leakage rate through the secondary (lower) geomembrane of the liner system.

This section evaluates potential leakage through the primary (upper) geomembrane of the double membrane and LCRS liner system at the process solution ponds. Excessive leakage rates, known as 'alert levels', may indicate that the primary geomembrane is not providing the desired level of hydraulic containment.

6.1 Introduction

This section documents calculation of alert level discharge rates from LCRS that are a component of a dual geomembrane – LCRS liner system at each of the process solution ponds. The discharge (i.e., flowrate) from a LCRS results primarily from leakage through imperfections in the primary (upper) geomembrane, such as pinholes resulting from the manufacturing process, incompletely sealed seams, cracks, tears, or perforations. Discharge from a LCRS that exceeds an alert level may be evidence of damage to or deterioration of the primary geomembrane, and hence may trigger actions such as additional monitoring, inspection, or repair.

Discharge values for two alert levels are calculated. Alert Level 1 is the discharge that corresponds to leakage through a 2-millimeter (mm) diameter circular hole (area = 3.1 square mm) that penetrates the primary geomembrane at a frequency of one hole per 4,000 square meters (m^2), which is approximately one hole per acre (1 acre = 4,047 m^2). Alert Level 2 is the discharge that corresponds to leakage through a 11.3 mm diameter (area = 1 square centimeter = 100 square mm) circular hole that penetrates the primary geomembrane at the same frequency. The size of the imperfections corresponds to the 'small hole' and 'standard hole' used for geomembrane leakage calculations described in *Background Document on Proposed Liner and Leak Detection Rule* (US EPA, 1987).

Alert levels apply only to liner systems that have a LCRS below a geomembrane. The following ponds are designed with dual geomembrane – LCRS liner systems, and thus alert levels are calculated for those ponds.

- Pregnant Solution Pond
- PSP – Solution
- PSP - Thickener
- Raffinate Pond
- Reclaim Pond.

6.2 Approach

Leakage through small holes and standard holes in a primary membrane into the LCRS immediately below it is calculated using the approach described in US EPA (1987) and in *Leakage Through Liners Constructed with Geomembranes – Part I: Geomembrane Liners* (Giroud and Bonaparte, 1989b). That approach is applicable to a geomembrane situated between two infinitely pervious media. In the cases evaluated here, water in a pond above the primary geomembrane and a geonet LCRS below the primary geomembrane both have much higher hydraulic conductivity than the geomembrane. This situation contrasts to the systems considered in Sections 3 and 4, in which single geomembranes or the lower geomembrane of a dual geomembrane liner are directly above low hydraulic conductivity material.

Bernoulli's equation for flow through an orifice is used for calculating the discharge through a hole in the geomembrane above a high hydraulic conductivity material such as a geonet.

$$Q = C\,a\,(2\,g\,h_w)^{0.5}$$

where a = cross sectional area of the hole

C = coefficient related to the shape of the edges of the hole; for sharp edges, C = 0.6 (dimensionless)

g = gravitational acceleration

h_w = hydraulic head at the top of the geomembrane (i.e., depth of water above the geomembrane)

Q = discharge through the geomembrane hole

USEPA (1989) recommended assuming the frequency of imperfections in the primary geomembrane is one imperfection per 4,000 m^2, which is nominally one imperfection per acre. The leakage rate through a geomembrane with different areal extent is linearly proportional to the rate for the assumed imperfection frequency and the areal extent of the membrane.

6.3 Input Information

Table 6-1 provides the pond area and design water depth for the process solution ponds. The pond area is used to scale the discharge based on the assumed frequency of imperfections to the pond size. The design depth is the total depth minus the required freeboard. The design water depth is the hydraulic head term in the Bernoulli orifice flow equation.

Table 6-1: Process Solution Ponds Parameter Values

Pond	Pond Area			Design Water Depth	
	(square feet)	(acres)	(square meters)	(feet)	(meters)
Pregnant Leach Solution Pond	139,500	3.2	12,960	22	6.7
Primary Settling Pond – Solution Cell	160,000	3.74	14,864	18	5.5
Primary Settling Pond – Thickener Cell	60,000	1.4	5,574	10	3.0
Raffinate Pond	65,400	1.5	6,076	22	6.7
Reclaim Pond	64,500	1.5	5,992	22	6.7

The discharge (leakage rate) through the primary geomembrane is calculated for a 'small hole' – 2 mm diameter, and a 'standard hole' – 1 cm^2 area, at a frequency of one hole per 4,000 m^2, consistent with USEPA (1989). Alert

Level 1 corresponds to the discharge through a small hole and alert level 2 corresponds to the discharge through a standard hole. The discharge for a given pond having area other than 4,000 m^2 is the discharge for a small hole or standard hole multiplied by the pond area divided by 4,000 m^2.

6.4 Results

Alert levels for the process solution ponds are provided in Table 6-2. Detailed calculations of the discharge for a small hole and standard hole and the corresponding alert levels for the subject ponds are provided in Attachment 1.

Table 6-2: Alert Levels for Process Solution Ponds

Pond	Alert Level 1			Alert Level 2		
	m^3/s	gal/min	gal/day	m^3/s	gal/min	gal/day
Pregnant Leach Solution	7.0E-05	1.11	1,600	2.2E-03	35	50,900
Primary Settling Pond – Solution Cell	7.3E-05	1.15	1,660	2.3E-03	37	52,800
Primary Settling Pond – Thickener Cell	2.0E-05	0.32	460	6.5E-04	10	14,800
Raffinate Pond	3.3E-05	0.52	750	1.0E-03	17	23,800
Reclaim Pond	3.2E-05	0.51	740	1.0E-03	16	23,500

7 References

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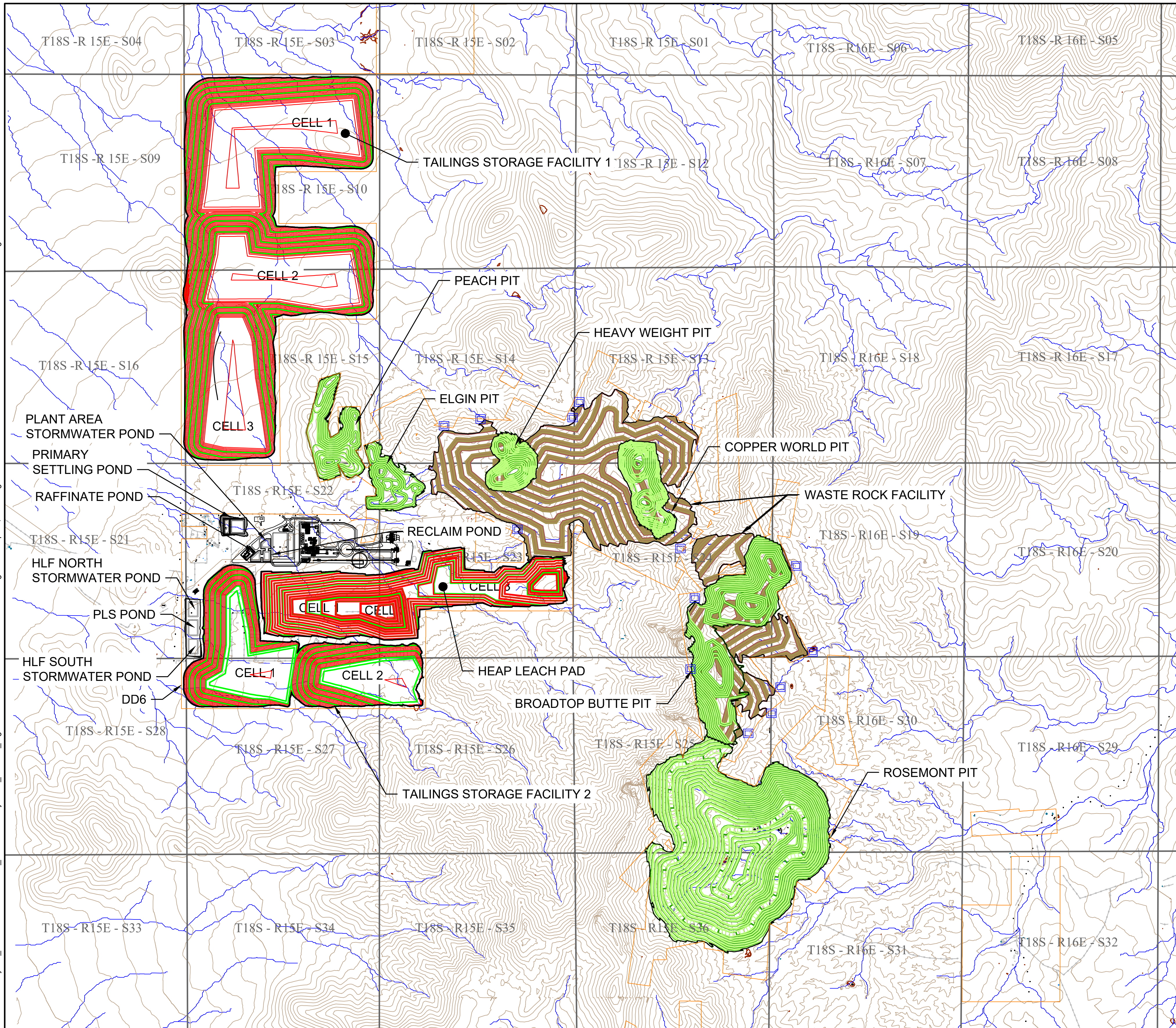
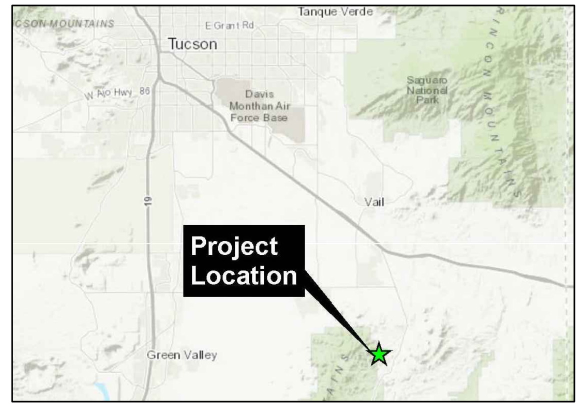
Figures



SITE PLAN

SCALE: 1" = 3000'

N



KEY PLAN

SCALE: N.T.S.

NOTE(S):

1. THIS FIGURE SHOULD BE READ IN CONJUNCTION WITH THE SITE WATER MANAGEMENT PLAN.

LEGEND:

3750	MAJOR CONTOURS ONLY		WASTE ROCK
	PROPERTY BOUNDARY		PIT EXCAVATION AREA
	PIMA COUNTY FLOODPLAIN WASHES		WRF SEDIMENT POND
	ROAD		TAILINGS/ HEAP LEACH PAD

0 3000' 6000'

ROSEMONT COPPER WORLD PROJECT

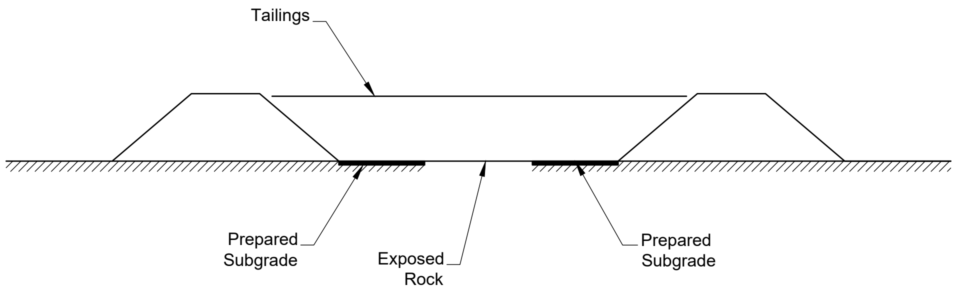
SITE LOCATIONS AND FACILITIES SUBJECT TO AN AQUIFER PROTECTION PERMIT

wood.

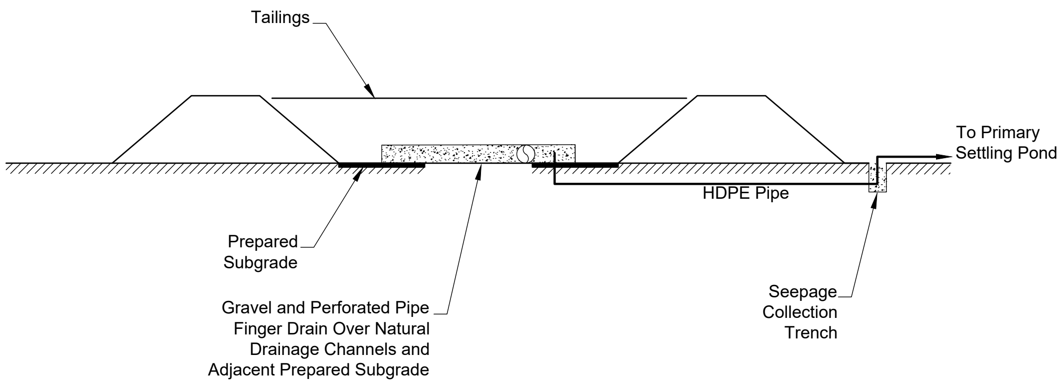
WOOD ENVIRONMENT & INFRASTRUCTURE SOLUTIONS
4600 E WASHINGTON ST, SUITE 600
PHOENIX, ARIZONA 85034
PHONE: 602-733-6000

By: OAS	Date: 21/12/21	Project No: 17-2021-4024	Figure: 1

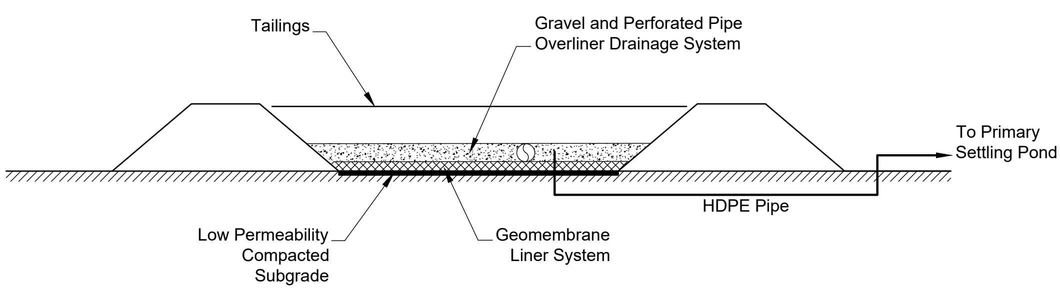
wood. Drawing Path: P:\2021\Projects_Other\1720214024.001_Rosemont Project\13_CAD\03_Figures\008 - 10-01-2022 - Site Water Management Report\, Drawing Name: FIG 1 - PROJECT LOCATION & FACILITY LAYOUT.dwg Plot Date: 06/24/22 - 11:08am



TSF ALTERNATIVE 1
Prepared Subgrade



TSF ALTERNATIVE 2
Finger Drain and Prepared Subgrade



TSF ALTERNATIVE 3
BADCT Geomembrane Liner System

TAILINGS STORAGE FACILITIES
BOTTOM CONFIGURATION
ALTERNATIVES
Rosemont Copper World Project
Pima County, Arizona

wood.	By: DPV	Proj. No.: 1720214024
	Date: 2/22/22	Figure 2

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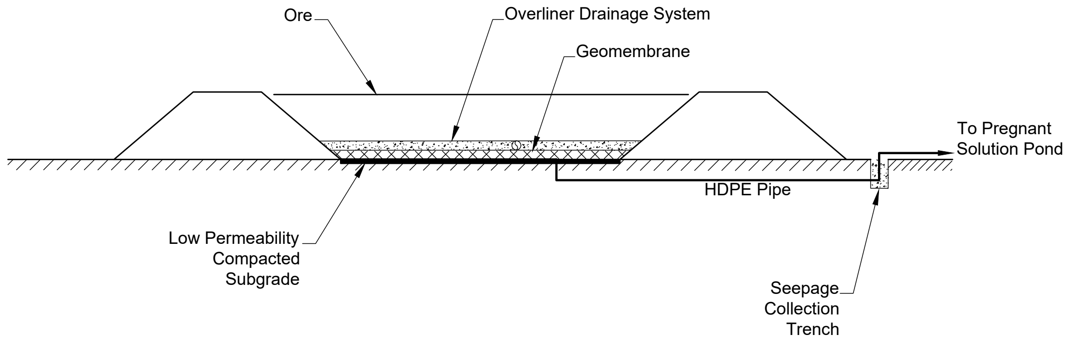
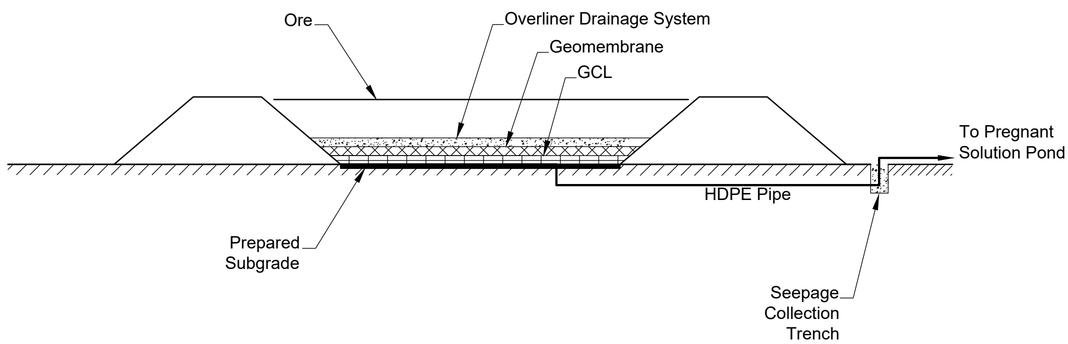


HLP ALTERNATIVE 1
BADCT Geomembrane Liner System



HLP ALTERNATIVE 2
Geomembrane on GCL Underliner with Overliner Drainage System

HEAP LEACH PAD BOTTOM
CONFIGURATION ALTERNATIVES
Rosemont Copper World Project
Pima County, Arizona

wood.	By: DPV	Proj. No.: 1720214024
	Date: 2/22/22	Figure 3

Plot Date: 06/21/22 - 6:10pm, Plotted by: donna.valasek
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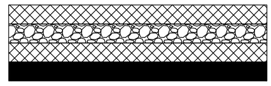
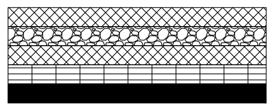
PROCESS SOLUTION PONDS

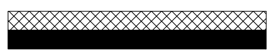


ALTERNATIVE 1
Dual Liner System on Compacted Subgrade

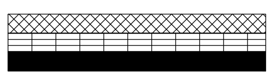


ALTERNATIVE 2
Dual Liner System on GCL

STORMWATER PONDS



ALTERNATIVE 1
Single Liner System on Prepared Subgrade



ALTERNATIVE 2
Single Liner System on GCL

POND BOTTOM CONFIGURATIONS
Rosemont Copper World Project
Pima County, Arizona

wood.	By: DPV	Proj. No.: 1720214024
	Date: 2/22/22	Figure 4

Plot Date: 06/22/22 - 10:01am, Plotted by: donna.valasek
Drawing Path: P:\Project\Inter-Office Projects\1720214024-Rosemont\, Drawing Name: Rosemont_ConfigAlternatives.dwg

Attachment 1: Tailings Storage Facilities Net Inflow Calculations

Table A1-1
Water Budget TSF-1 Alternative 1
Rosemont Copper World Project
Pima County, Arizona

Year	Percent Tailings to TSF-1[1]	TSF-1 Tailings Interstitial Water[1]	Non-Drainable Interstitial Water in TSF-1 Tailings[1]	Drainable Interstitial Water in TSF-1 Tailings[1]	Precipitation on TSF-1 Tailings[1]	Evaporation from TSF-1 Tailings[1]	TSF-1 Drainable Interstitial Water + Precipitation - Evaporation[1]	TSF-1 Decant Water to PSP[1]	TSF -1 Total Seepage[1]	TSF-1 Seepage Captured by Underdrain[2]	TSF-1 Seepage Potentially Discharging to Environment[2]
	%	gpm	gpm	gpm	gpm	gpm	gpm	gpm	gpm	gpm	gpm
1	100%	1,366	736	630	283	593	320	21	299	0	299
2	100%	2,049	1,105	945	317	665	597	262	335	0	335
3	100%	2,049	1,105	945	351	735	561	190	370	0	370
4	100%	2,049	1,105	945	385	806	523	117	406	0	406
5	100%	4,099	2,209	1,889	469	983	1,375	880	496	0	496
6	100%	4,099	2,209	1,889	506	1,060	1,335	801	535	0	535
7	100%	4,099	2,209	1,889	543	1,137	1,295	722	573	0	573
8	100%	4,099	2,209	1,889	579	1,214	1,255	643	612	0	612
9	100%	4,099	2,209	1,889	616	1,290	1,215	565	651	0	651
10	90%	3,689	1,989	1,700	653	1,367	986	297	689	0	689
11	80%	3,279	1,768	1,512	718	1,471	759	0	759	0	759
12	60%	2,459	1,326	1,134	718	1,093	759	0	759	0	759
13	40%	1,640	884	756	718	715	759	0	759	0	759
14	20%	820	442	378	718	338	759	0	759	0	759
15	0%	0	0	0	718	0	718	0	759	0	759

Notes:

1. Values from *Site-Wide Water Balance* (Wood, 2022)

2. Modifed from *Site-Wide Water Balance* (Wood, 2022) values due to absence of an underdrain

Table A1-2
Water Budget TSF-1 Alternative 2
Rosemont Copper World Project
Pima County, Arizona

Year	Percent Tailings to TSF-1[1]	TSF-1 Tailings Interstitial Water[1]	Non-Drainable Interstitial Water in TSF-1 Tailings[1]	Drainable Interstitial Water in TSF-1 Tailings[1]	Precipitation on TSF-1 Tailings[1]	Evaporation from TSF-1 Tailings[1]	TSF-1 Drainable Interstitial Water + Precipitation - Evaporation[1]	TSF-1 Decant Water to PSP[1]	TSF -1 Total Seepage[1]	TSF-1 Seepage Captured by Underdrain[2]	TSF-1 Seepage Potentially Discharging to Environment[2]
	%	gpm	gpm	gpm	gpm	gpm	gpm	gpm	gpm	gpm	gpm
1	100%	1,366	736	630	283	593	320	21	299	239	60
2	100%	2,049	1,105	945	317	665	597	262	335	268	67
3	100%	2,049	1,105	945	351	735	561	190	370	296	74
4	100%	2,049	1,105	945	385	806	523	117	406	325	81
5	100%	4,099	2,209	1,889	469	983	1,375	880	496	397	99
6	100%	4,099	2,209	1,889	506	1,060	1,335	801	535	428	107
7	100%	4,099	2,209	1,889	543	1,137	1,295	722	573	459	115
8	100%	4,099	2,209	1,889	579	1,214	1,255	643	612	489	122
9	100%	4,099	2,209	1,889	616	1,290	1,215	565	651	520	130
10	90%	3,689	1,989	1,700	653	1,367	986	297	689	551	138
11	80%	3,279	1,768	1,512	718	1,471	759	0	759	607	152
12	60%	2,459	1,326	1,134	718	1,093	759	0	759	607	152
13	40%	1,640	884	756	718	715	759	0	759	607	152
14	20%	820	442	378	718	338	759	0	759	607	152
15	0%	0	0	0	718	0	718	0	759	607	152

Notes:

1. Values from *Site-Wide Water Balance* (Wood, 2022)

2. Modifed from *Site-Wide Water Balance* (Wood, 2022) values for 80 percent capture of seepage by a finger underdrain system

Table A1-3

Water Budget TSF-2 Alternative 1

Rosemont Copper World Project

Pima County, Arizona

Year	Percent Tailings to TSF-1[1]	TSF-1 Tailings Interstitial Water[1]	Non-Drainable Interstitial Water in TSF-1 Tailings[1]	Drainable Interstitial Water in TSF-1 Tailings[1]	Precipitation on TSF-1 Tailings[1]	Evaporation from TSF-1 Tailings[1]	TSF-1 Drainable Interstitial Water + Precipitation - Evaporation[1]	TSF-1 Decant Water to PSP[1]	TSF -1 Total Seepage[1]	TSF-1 Seepage Captured by Underdrain[2]	TSF-1 Seepage Potentially Discharging to Environment[2]
	%	gpm	gpm	gpm	gpm	gpm	gpm	gpm	gpm	gpm	gpm
1	0%	0	0	0	0	0	0	0	0	0	0
2	0%	0	0	0	0	0	0	0	0	0	0
3	0%	0	0	0	0	0	0	0	0	0	0
4	0%	0	0	0	0	0	0	0	0	0	0
5	0%	0	0	0	0	0	0	0	0	0	0
6	0%	0	0	0	0	0	0	0	0	0	0
7	0%	0	0	0	0	0	0	0	0	0	0
8	0%	0	0	0	0	0	0	0	0	0	0
9	0%	0	0	0	0	0	0	0	0	0	0
10	10%	410	221	189	67	92	164	0	164	0	164
11	20%	820	442	378	86	253	210	0	210	0	210
12	40%	1,640	884	756	105	360	501	244	257	0	257
13	60%	2,459	1,326	1,134	123	424	833	530	303	0	303
14	80%	3,279	1,768	1,512	142	489	1,165	816	349	0	349
15	100%	3,421	1,844	1,577	154	528	1,202	825	377	0	377

Notes:

1. Values from *Site-Wide Water Balance* (Wood, 2022)

2. Modifed from *Site-Wide Water Balance* (Wood, 2022) values for 80 percent capture of seepage by a finger underdrain system

Table A1-4

Water Budget TSF-2 Alternative 2

Rosemont Copper World Project

Pima County, Arizona

Year	Percent Tailings to TSF-1[1]	TSF-1 Tailings Interstitial Water[1]	Non-Drainable Interstitial Water in TSF-1 Tailings[1]	Drainable Interstitial Water in TSF-1 Tailings[1]	Precipitation on TSF-1 Tailings[1]	Evaporation from TSF-1 Tailings[1]	TSF-1 Drainable Interstitial Water + Precipitation - Evaporation[1]	TSF-1 Decant Water to PSP[1]	TSF -1 Total Seepage[1]	TSF-1 Seepage Captured by Underdrain[2]	TSF-1 Seepage Potentially Discharging to Environment[2]
	%	gpm	gpm	gpm	gpm	gpm	gpm	gpm	gpm	gpm	gpm
1	0%	0	0	0	0	0	0	0	0	0	0
2	0%	0	0	0	0	0	0	0	0	0	0
3	0%	0	0	0	0	0	0	0	0	0	0
4	0%	0	0	0	0	0	0	0	0	0	0
5	0%	0	0	0	0	0	0	0	0	0	0
6	0%	0	0	0	0	0	0	0	0	0	0
7	0%	0	0	0	0	0	0	0	0	0	0
8	0%	0	0	0	0	0	0	0	0	0	0
9	0%	0	0	0	0	0	0	0	0	0	0
10	10%	410	221	189	67	92	164	0	164	131	33
11	20%	820	442	378	86	253	210	0	210	168	42
12	40%	1,640	884	756	105	360	501	244	257	205	51
13	60%	2,459	1,326	1,134	123	424	833	530	303	242	61
14	80%	3,279	1,768	1,512	142	489	1,165	816	349	279	70
15	100%	3,421	1,844	1,577	154	528	1,202	825	377	302	75

Notes:

1. Values from *Site-Wide Water Balance* (Wood, 2022)

2. Modifed from *Site-Wide Water Balance* (Wood, 2022) values for 80 percent capture of seepage by a finger underdrain system

Attachment 2: Tailings Storage Facilities Discharge Calculations

Table A2-1

Properties of Geologic Units in Tailings Storage Facilities and Heap Leach Pad Footprints

Rosemont Copper World Project

Pima County, Arizona

Geologic Unit	Hydraulic Conductivity (m^2/s)	Outcrop Area[1] (ft^2)	Outcrop Area (acres)	Outcrop Area (m^2)
Tailings Storage Facility 1				
Basin Fill (QTg)	2.4E-04	8,847,150	203.1	821,920
Horquilla Limestone - (Ph)	5.0E-07	38,964	0.9	3,620
Paleocene Deposits (Tir)	5.0E-08	119,097	2.7	11,064
Permian Sedimentary Deposits - Naco Formation (PCc)	5.0E-08	1,123,184	25.8	104,346
Recent Alluvium (Qal)	2.4E-04	2,227,737	51.1	206,962
Tertiary Granodiorite Qtz Monzonite (Tgr)	1.0E-08	1,454,261	33.4	135,104
	Totals	***13,810,393***	***317***	***1,283,017***
Tailings Storage Facility 2				
Basin Fill (QTg)	2.4E-04	3,980,834	91.4	369,829
Tertiary Granodiorite Qtz Monzonite (Tgr)	1.0E-08	598,955	13.8	55,644
	Totals	***4,579,789***	***105***	***425,473***
Heap Leach Pad				
Basin Fill (QTg)	2.4E-04	8,692,701	199.6	807,572
Permian Sedimentary Deposits - Naco Formation (PCc)	1.0E-08	1,077,175	24.7	100,072
Recent Alluvium (Qal)	2.4E-04	496,001	11.4	46,080
Tertiary Granodiorite Qtz Monzonite (Tgr)	1.0E-08	911,638	20.9	84,693
	Totals	***11,177,514***	***257***	***1,038,416***

Note(s)

1. In footprint bounded by inner toe of embankments

2. 1 acre = 43,560 ft^2

3. 1 m^2 = 10.764 ft^2

Abbreviation(s)

ft = foot or feet

m = meter or meters

s = second

Table A2-2

Tailings Storage Facility 1 - Alternatives 1 and 2 - Unlined Bottom

Rosemont Copper World Project

Pima County, Arizona

Geologic Unit	Hydraulic Conductivity (m^2/s)	Outcrop Area[1] (m^2)	Darcy Discharge (m^3/s)	Darcy Discharge (gal/min)	Darcy Discharge (gal/day)
Basin Fill (QTg)	2.4E-04	821,920	197	3,126,585	4,502,282,155
Horquilla Limestone - (Ph)	5.0E-07	3,620	0.002	29	41,309
Paleocene Deposits (Tir)	5.0E-08	11,064	0.001	9	12,627
Permian Sedimentary Deposits - Naco Formation (PCc)	5.0E-08	104,346	0.005	83	119,080
Recent Alluvium (Qal)	2.4E-04	206,962	50	787,283	1,133,687,234
Tertiary Granodiorite Qtz Monzonite (Tgr)	1.0E-08	135,104	0.001	21	30,836
		Total	***247***	***3,914,009***	***5,636,173,241***

Note(s)

1. In footprint bounded by inner toe of embankments

Abbreviation(s)

ft = foot or feet

gal = US gallons

m = meter or meters

min = minute

s = second

Assumptions:

1) 1-D steady-state seepage described by Darcy Equation

2) Hydraulic conductivity and area specific to each geologic unit used

3) Saturated hydraulic conductivity values used

4) Vertical hydraulic gradient i = 1 based on vertical flow with steady state water content

Conversion Factors

1 m^3/s =	15,850	gal/min
1 gal/min =	1,440	gal/day

Darcy Equation

$Q_{infiltration} = K\ i\ A$

where

$Q_{infiltration}$ = infiltration rate (m^3/s)

K = hydraulic conductivity (m/s)

i = hydraulic gradient (m/m)

A = area (m^2)

Table A2-3

Tailings Storage Facility 1 - Alternative 3 - Geomembrane Liner With Overliner Drain and Compacted Subgrade

Rosemont Copper World Project

Pima County, Arizona

Geologic Unit	Hydraulic Conductivity (m^2/s)	Area[1] (m^2)	Leakage[2] per 4000 m^2 (m^3/s)	Leakage (m^3/s)	Leakage (gal/min)	Leakage (gal/day)
Compacted subgrade	1.0E-08	1,283,017	6.3E-08	2.0E-05	0.32	465
			Total	***2.0E-05***	***0.32***	***465***

Note(s)

1. In footprint bounded by inner toe of embankments
2. Giroud et al. (1994) calculates leakage rate per 4000 m^2

Abbreviation(s)

gal = US gallons

m = meter or meters

min = minutes

s = second

Assumptions:

1) 1-D steady-state leakage through 1 cm^2 defect per 4000 m^2 liner area

2) Membrane is in good contact with underlying soil

3) Hydraulic conductivity of compacted subgrade is 1×10^{-6} cm/s

4) Head at bottom of TSF is 2 feet = 0.6 m

Conversion Factors

1 m^3/s =	15,850	gal/min
1 gal/min =	1,440	gal/day

Giroud at al. (1994) Leakage through defect in membrane over thick soil underliner

$Q = c\, a^{0.1} h^{0.9} K^{0.74}$

where:

Q = leakage rate (m^3/s) per 4000 m^2 of membrane

a = area of defect in membrane (m^2)	1.0E-04
c = membrane:underliner contact coefficient	0.21
h = hydraulic head at top of membrane (m)	0.6

K = hydraulic conductivity of material below geomembrane (m/s)

Table A2-4

Tailings Storage Facility 2 - Alternatives 1 and 2 - Unlined Bottom

Rosemont Copper World Project

Pima County, Arizona

Geologic Unit	Hydraulic Conductivity (m^2/s)	Outcrop Area[1] (m^2)	Darcy Discharge (m^3/s)	Darcy Discharge (gal/min)	Darcy Discharge (gal/day)
Basin Fill (QTg)	2.4E-04	369,829	89	1,406,828	2,025,831,962
Tertiary Granodiorite Qtz Monzonite (Tgr)	1.0E-08	55,644	0.0006	9	12,700
		Total	***89***	***1,406,837***	***2,025,844,662***

Note(s)

1. In footprint bounded by inner toe of embankments

Abbreviation(s)

gal = US gallons

m = meter or meters

min = minute

s = second

Assumptions:

1) 1-D steady-state seepage described by Darcy Equation

2) Hydraulic conductivity and area specific to each geologic unit used

3) Saturated hydraulic conductivity values used

4) Vertical hydraulic gradient i = 1 based on vertical flow with steady state water content

Conversion Factors

1 m^3/s =	15,850	gal/min
1 gal/min =	1,440	gal/day

Darcy Equation

$Q_{infiltration} = K\ i\ A$

where

Qinfiltration = infiltration rate (m^3/s)

K = hydraulic conductivity (m/s)

i = hydraulic gradient (m/m)

A = area (m^2)

Table A2-5

Tailings Storage Facility 2 - Alternative 3 - Geomembrane Liner With Overliner Drain and Compacted Subgrade

Rosemont Copper World Project

Pima County, Arizona

Geologic Unit	Hydraulic Conductivity (m^2/s)	Area[1] (m^2)	Leakage[2] per 4000 m^2 (m^3/s)	Leakage (m^3/s)	Leakage (gal/min)	Leakage (gal/day)
Compacted subgrade	1.0E-08	425,473	6.3E-08	6.8E-06	0.11	154
			Total	***6.8E-06***	***0.11***	***154***

Note(s)

1. In footprint bounded by inner toe of embankments
2. Giroud et al. (1994) calculates leakage rate per 4000 m^2

Abbreviation(s)

gal = US gallons

m = meter or meters

min = minutes

s = second

Assumptions:

1) 1-D steady-state leakage through 1 cm^2 defect per 4000 m^2 liner area

2) Membrane is in good contact with underlying soil

3) Hydraulic conductivity of compacted subgrade is 1×10^{-6} cm/s

4) Head at bottom of TSF is 2 feet = 0.6 m

Conversion Factors

1 m^3/s =	15,850	gal/min
1 gal/min =	1,440	gal/day

Giroud at al. (1994) Leakage through defect in membrane over thick soil underliner

$Q = c\, a^{0.1} h^{0.9} K^{0.74}$

where:

Q = leakage rate (m^3/s) per 4000 m^2 of membrane

a = area of defect in membrane (m^2)	1.0E-04
c = membrane:underliner contact coefficient	0.21
h = hydraulic head at top of membrane (m)	0.6
K = hydraulic conductivity of material below geomembrane (m/s)	

Table A2-6

Discharge from TSFs 1 and 2 Constrained by Water Availability

Rosemont Copper World Project

Pima County, Arizona

Facility	Alternative	Maximum Available Inflow[1,2] (gal/min)	Darcy Discharge[3] With Unlimited Water Availability (gal/min)	Membrane Leakage[4] with Unlimited Water Availability (gal/min)	Discharge from Facility[5] (gal/min)	Discharge from Facility[5] (gal/day)
TSF-1	1 - Unlined, no underdrain	759	3,914,009	—	759	1,092,672
	2 - Unlined, finger underdrain	152	3,914,009	—	152	218,534
	3- Geomembrane on compacted subgrade and overliner drain	152	—	0.32	0.32	465
TSF-2	1 - Unlined, no underdrain	377	1,406,837	—	377	542,880
	2 - Unlined, underdrain	75	1,406,837	—	75	108,576
	3- Geomembrane on compacted subgrade and overliner drain	75	—	0.11	0.11	154

Note(s)

1. TSF net inflow calculations provided in Table A1-1. The maximum value for all mine operating years selected.
2. HLP net inflow = 3000 gpm solution application rate minus 44 gpm evaporation
3. TSF-1 and TSF-2 Alternatives 1 and 2
4. TSF-1 and TSF-2 Alternative 3
5. The smaller of (discharge or leakage with unlimited water availability) and water available as net inflow

Abbreviation(s)

gal = gallons

min = minutes

Conversion Factors

1 m^3/s =	15,850	gal/min
1 gal/min =	1,440	gal/day

Attachment 3: Heap Leach Pad Discharge Calculations

Table A3-1

Heap Leach Pad - Alternative 1 - Geomembrane Liner Over Compacted Subgrade

Rosemont Copper World Project

Pima County, Arizona

Geologic Unit	Hydraulic Conductivity (m^2/s)	Area[1] (m^2)	Leakage[2] per 4000 m^2 (m^3/s)	Leakage (m^3/s)	Leakage (gal/min)	Leakage (gal/day)
Compacted Subgrade	1.0E-08	1,359,745	6.3E-08	2.2E-05	0.34	492
			Total	***2.2E-05***	***0.34***	***492***

Note(s)

1. Area = 336 acres

2. Giroud et al. (1994) calculates leakage rate per 4000 m^2

Abbreviation(s)

gal = US gallons

m = meter or meters

min = minutes

s = second

Assumptions:

1) 1-D steady-state leakage through 1 cm^2 defect per 4000 m^2 liner area

2) Membrane is in good contact with underlying soil

3) Hydraulic conductivity of compacted subgrade is $1x10^{-6}$ cm/s

4) Head at bottom of TSF is 2 feet = 0.6 m

Conversion Factors

1 m^3/s =	15,850	gal/min
1 gal/min =	1,440	gal/day

Giroud at al. (1994) Leakage through defect in membrane over thick soil underliner

$Q= ca^{0.1}h^{0.9}K^{0.74}$

where:

Q = leakage rate (m^3/s) per 4000 m^2 of membrane

a = area of defect in membrane (m^2)	1.0E-04
c = membrane:underliner contact coefficient	0.21
h = hydraulic head at top of membrane (m)	0.6
K = hydraulic conductivity of material below geomembrane (m/s)	

Table A3-2

Heap Leach Pad - Alternative 2 - Geomembrane Liner Over GCL Underliner

Rosemont Copper World Project

Pima County, Arizona

Geologic Unit	Hydraulic Conductivity (m^2/s)	Area[1] (m^2)	Leakage[2] per 4000 m^2 (m^3/s)	Leakage (m^3/s)	Leakage (gal/min)	Leakage (gal/day)
GCL	5.0E-11	1,359,745	1.0E-08	3.4E-06	0.05	78
			Total	***3.4E-06***	***0.05***	***78***

Note(s)

1. Area = 336 acres
2. Giroud et al. (1994) calculates leakage rate per 4000 m^2

Conversion Factors

1 m^3/s =	15,850	gal/min
1 gal/min =	1,440	gal/day

Abbreviation(s)

gal = US gallons

GCL = geotextile clay liner

m = meter or meters

min = minutes

s = second

Assumptions:

1) 1-D steady-state leakage through 1 cm^2 defect per 4000 m2 liner area

2) Membrane is in good contact with underlying GCL

3) GCL is much thinner than the head above the geomembrane

4) GCL thickness = 1/4 inch = 0.006 m

5) Saturated hydraulic conductivity of GCL 5 E-11 m/s

6) Head at bottom of HLP is 2 foot = 0.6 m

Giroud at al. (1994) Leakage through defect in membrane over thin GCL underliner

$Q=c\, i_{avg}\, a^{0.1} h^{0.9} K^{0.74}$

where:

Q = leakage rate (m^3/s) per 4000 m^2 of membrane

a = area of defect in membrane (m^2)	1.0E-04
c = membrane:underliner contact coefficient	0.21
h = hydraulic head at top of membrane (m)	0.6
K = hydraulic conductivity of material below geomembrane (m/s)	5.0E-11
D = GCL underliner thickness (m)	0.006
h/D = ratio of head to underliner thickness (m/m)	1.0E+02
i_{avg} = coefficient that depends on h/D, determined from Figure 1 of Giroud et al., 1994	8

Table A3-2

Heap Leach Pad - Alternative 2 - Geomembrane Liner Over GCL Underliner

Rosemont Copper World Project

Pima County, Arizona

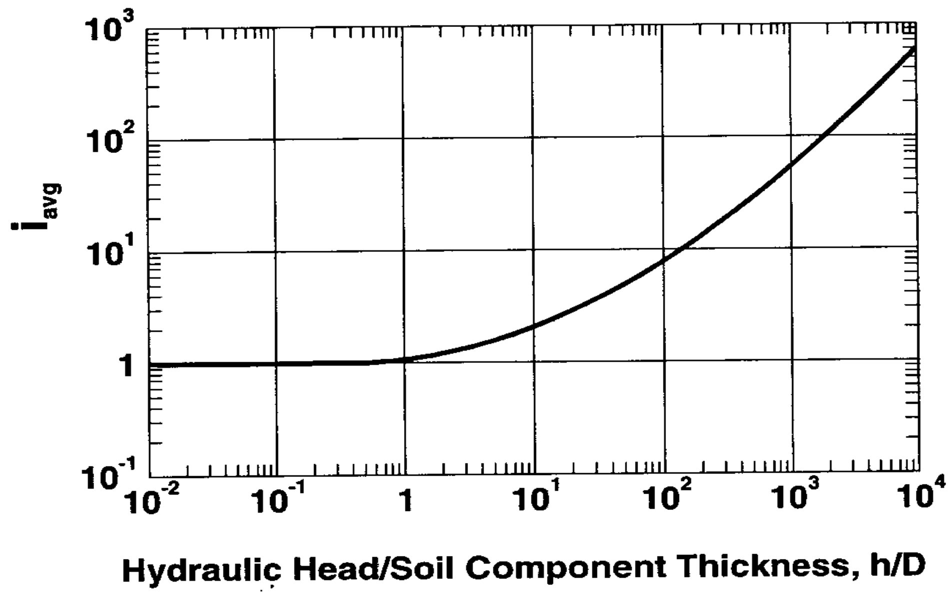


Fig. 1 Value of i_{avg} .

J.P. Giroud, K. Badu-Twaneboah, and K.L. Soderman, *Evaluation of Landfill Liners.* Page 981. Fifth International Conference on Geotextiles and Related Products. Singapore, September 5-9, 1994.

Table A3-3

Discharge from Heap Leach Pad Constrained by Water Availability

Rosemont Copper World Project

Pima County, Arizona

Facility	Alternative	Maximum Available Inflow[1] (gal/min)	Membrane Leakage with Unlimited Water Availability (gal/min)	Discharge from Facility[2] (gal/min)	Discharge from Facility[2] (gal/day)
HLP	1- Geomembrane on thick soil underliner	2,956	0.34	0.34	492
	2 - Geomembrane on thin GCL underliner	2,956	0.05	0.05	78

Note(s)

1. HLF net inflow = 3,000 gpm solution application rate minus 44 gpm evaporation

2. The smaller of membrane leakage with unlimited water availability and water available as net inflow

Abbreviation(s)

gal = gallons

min = minutes

Conversion Factors

1 m^3/s =	15,850	gal/min
1 gal/min =	1,440	gal/day

Attachment 4: Process Solution Ponds and Stormwater Ponds Discharge Calculations

Table A4-1
Process Solution Ponds Discharge
Rosemont Copper World
Pima County, Arizona

Pond	Area		Membrane : Underliner Contact Coefficient[1] c	Hydraulic Head[2] h	Thickness of Underliner[3] D	h/D	i_{avg}[4]	Defect Area a	Hydraulic Conductivity of Underliner K	Leakage[5] per 4000 m^2 Q_{4000}	Leakage through Pond Bottom Q_{pond}		
	(acres)	(m^2)	(-)	(m)	(m)	(-)	(-)	(m^2)	(m/s)	(m^3/s)	(m^3/s)	(gal/day)	(gal/year)
Process Solution Ponds													
Primary Settline Pond - Alternative 1[6]	5.1	20,450	0.21	0.006	0.15	0.04	1	1.0E-04	1.0E-08	1.0E-09	5.1E-09	0.12	43
Primary Settline Pond - Alternative 2[7]					0.006	1	1		5.0E-11	2.0E-11	1.0E-10	0.0023	0.85
Pregnant Solution Pond - Alternative 1[6]	3.2	12,960	0.21	0.006	0.15	0.04	1	1.0E-04	1.0E-08	1.0E-09	3.3E-09	0.074	27
Pregnant Solution Pond - Alternative 2[7]					0.006	1	1		5.0E-11	2.0E-11	6.5E-11	0.0015	0.54
Raffinate Pond - Alternative 1[6]	1.5	6,079	0.21	0.006	0.15	0.04	1	1.0E-04	1.0E-08	1.0E-09	1.5E-09	0.035	13
Raffinate Pond - Alternative 2[7]					0.006	1	1		5.0E-11	2.0E-11	3.0E-11	0.0007	0.25
Reclaim Pond - Alternative 1[6]	1.5	5,992	0.21	0.006	0.15	0.04	1	1.0E-04	1.0E-08	1.0E-09	1.5E-09	0.034	13
Reclaim Pond - Alternative 2[7]					0.006	1	1		5.0E-11	2.0E-11	3.0E-11	0.0007	0.25

Note(s)

1. Good contact between geomembrand and soil or GCL underliner
2. Hydraulic head on lower liner of double membrae system with drained geonet leakage collection system equals the thickness of the geonet. Hydraulic head on single geomembrane liner is the depth of water in pond (top of embankment minus freeboard)
3. Thickness of GCL underlineror compacted soil base below geomembrane
4. Determined using Figure 1 of Giroud et al., 1994
5. Equations in Grroud et al. 1994 calculate leakage rate for one defect per 4000 m^2
6. Alternative 1: Dual geomembrane liner with geonet LCRS on compacted subgrade
7. Alternative 2: Dual geomembrane liner with geonet LCRS on GCL underliner

Abbreviation(s)

gal = US gallons
m = meters
s = seconds

Conversion Factors

1	m3/s	15,850	gal/min
1	gal/min	1,440	gal/day
1	gal/day	365	gal/year

Giroud at al. (1994) Leakage through defect in membrane over thin GCL underliner or compacted soil base

$$Q = c\, i_{avg}\, a^{0.1} h^{0.9} K^{0.74}$$

where:
Q = leakage rate (m^3/s) per 4000 m^2 of membrane
a = area of defect in membrane (m^2)
c = membrane:underliner contact coefficient
h = hydraulic head at top of membrane (m)
K = hydraulic conductivity of material below geomembrane (m/s)
D = GCL underliner thickness (m)
h/D = ratio of head to underliner thickness (m/m)
i_{avq} = coefficient that depends on h/D, determined from Figure 1 of Giroud et al., 1994

Table A4-1

Process Solution Ponds Discharge

Rosemont Copper World

Pima County, Arizona

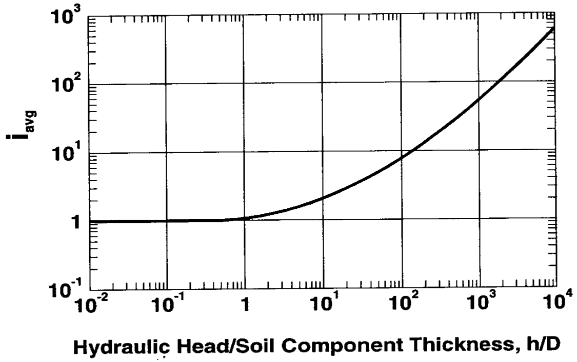


Fig. 1 Value of i_{avg} .

J.P. Giroud, K. Badu-Twaneboah, and K.L. Soderman, *Evaluation of Landfill Liners.* Page 981. Fifth International Conference on Geotextiles and Related Products. Singapore, September 5-9, 1994.

Table A4-2
Stormwater Ponds Discharge
Rosemont Copper World
Pima County, Arizona

Pond	Area		Membrane : Underliner Contact Coefficient[1] c	Hydraulic Head[2] h	Thickness of Underliner[3] D	h/D	i_{avg}[4]	Defect Area a	Hydraulic Conductivity of Underliner K	Leakage[5] per 4000 m^2 Q_{4000}	Leakage through Pond Bottom Q_{pond}		
	(acres)	(m^2)	(-)	(m)	(m)	(-)	(-)	(m^2)	(m/s)	(m^3/s)	(m^3/s)	(gal/day)	(gal/year)
Stormwater Ponds													
Process Area Stormwater Pond - Alt. 1[6]	1.5	6,044	0.21	6.7	0.15	45	4	1.0E-04	1.0E-08	2.2E-06	3.4E-06	77	28,100
Process Area Stormwater Pond - Alt. 2[7]					0.006	1,118	50		5.0E-11	5.5E-07	8.3E-07	19	7,000
North HLP Stormwater Pond - Alt 1.[6]	3.0	12,319	0.21	6.7	0.15	45	4	1.0E-04	1.0E-08	2.2E-06	6.9E-06	157	57,200
North HLP Stormwater Pond - Alt. 2[7]					0.006	1,118	50		5.0E-11	5.5E-07	1.7E-06	39	14,200
South HLP Stormwater Pond - Alt. 1[6]	3.0	12,319	0.21	6.7	0.15	45	4	1.0E-04	1.0E-08	2.2E-06	6.9E-06	157	57,200
South HLP Stormwater Pond - Alt. 2[7]					0.006	1,118	50		5.0E-11	5.5E-07	1.7E-06	39	14,200

Note(s)

1. Good contact between geomembrand and soil or GCL underliner
2. Hydraulic head on lower liner of double membrae system with drained geonet leakage collection system equals the thickness of the geonet. Hydraulic head on single geomembrane liner is the depth of water in pond (top of embankment minus freeboard)
3. Thickness of GCL underlineror compacted soil base below geomembrane
4. Determined using Figure 1 of Giroud et al., 1994
5. Equations in Grroud et al. 1994 calculate leakage rate for one defect per 4000 m^2
6. Alternative 1: Single geomembrane liner on compacted subgrade
7. Alternative 2: Single geomembrane liner on GCL underliner

Abbreviation(s)

gal = US gallons
m = meters
s = seconds

Conversion Factors

1	m3/s	15,850	gal/min
1	gal/min	1,440	gal/day
1	gal/day	365	gal/year

Giroud at al. (1994) Leakage through defect in membrane over thin GCL underliner or compacted soil base

$$Q = c\, i_{avg}\, a^{0.1} h^{0.9} K^{0.74}$$

where:
Q = leakage rate (m^3/s) per 4000 m^2 of membrane
a = area of defect in membrane (m^2)
c = membrane:underliner contact coefficient
h = hydraulic head at top of membrane (m)
K = hydraulic conductivity of material below geomembrane (m/s)
D = GCL underliner thickness (m)
h/D = ratio of head to underliner thickness (m/m)
i_{avg} = coefficient that depends on h/D, determined from Figure 1 of Giroud et al., 1994

Table A4-2

Stormwater Ponds Discharge

Rosemont Copper World

Pima County, Arizona

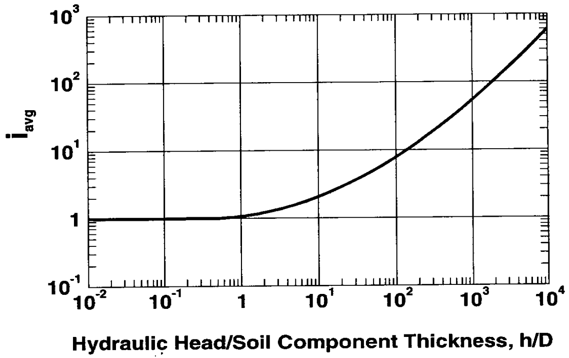


Fig. 1 Value of i_{avg} .

J.P. Giroud, K. Badu-Twaneboah, and K.L. Soderman, *Evaluation of Landfill Liners.* Page 981. Fifth International Conference on Geotextiles and Related Products. Singapore, September 5-9, 1994.

Table A4-3
Process Solution Ponds Discharge
Rosemont Copper World
Pima County, Arizona

Pond	Area		Hydraulic Conductivity of Underliner[1] K	Leakage[1] per 4000 m^2 Q_{4000}	Leakage Through Pond Bottom Q_{pond}		
	(acres)	(m^2)	(m/s)	(m^3/s)	(m^3/s)	(gal/day)	(gal/year)
Primary Settline Pond - Alternative 1[2]	5.1	20,450	1.0E-08	2.0E-11	5.1E-09	0.12	43
Primary Settline Pond - Alternative 2[3]			5.0E-11	1.0E-09	1.0E-10	0.0023	0.85
Pregnant Solution Pond - Alternative 1[2]	3.2	12,960	1.0E-08	2.0E-11	3.3E-09	0.074	27
Pregnant Solution Pond - Alternative 2[3]			5.0E-11	1.0E-09	6.5E-11	0.0015	0.54
Raffinate Pond - Alternative 1[2]	1.5	6,079	1.0E-08	2.0E-11	1.5E-09	0.035	13
Raffinate Pond - Alternative 2[3]			5.0E-11	1.0E-09	3.0E-11	0.0007	0.25
Reclaim Pond - Alternative 1[2]	1.5	5,992	1.0E-08	2.0E-11	1.5E-09	0.034	13
Reclaim Pond - Alternative 2[3]			5.0E-11	0.0E+00	3.0E-11	0.0007	0.25

Note(s)

1. Equations in Grroud et al. 1994 calculate leakage rate for one defect per 4000 m^2
2. Alternative 1: Dual geomembrane liner with geonet LCRS on compacted subgrade
3. Alternative 2: Dual geomembrane liner with geonet LCRS on GCL underliner

Abbreviation(s)

gal = US gallons
K + hydraulic conductivity
m = meters
Q_{4000} = leakage rate per 4,000 square meters of liner
Q_{Pond} = leakage rate from entire pond
s = seconds

Table A4-4

Stormwater Ponds Discharge

Rosemont Copper World

Pima County, Arizona

Pond	Area		Hydraulic Conductivity of Underliner K	Leakage[1] per 4000 m^2 Q_{4000}	Leakage through Pond Bottom Q_{pond}		
	(acres)	(m^2)	(m/s)	(m^3/s)	(m^3/s)	(gal/day)	(gal/year)
Process Area Stormwater Pond - Alt. 1[6]	1.5	6,044	1.0E-08	2.2E-06	3.4E-06	77	28,100
Process Area Stormwater Pond - Alt. 2[7]			5.0E-11	5.5E-07	8.3E-07	19	7,000
North HLP Stormwater Pond - Alt 1.[6]	3.0	12,319	1.0E-08	2.2E-06	6.9E-06	157	57,200
North HLP Stormwater Pond - Alt. 2[7]			5.0E-11	5.5E-07	1.7E-06	39	14,200
South HLP Stormwater Pond - Alt. 1[6]	3.0	12,319	1.0E-08	2.2E-06	6.9E-06	157	57,200
South HLP Stormwater Pond - Alt. 2[7]			5.0E-11	5.5E-07	1.7E-06	39	14,200

Note(s)

1. Hydraulic conductivity of compacted soil base below geomembrane
2. Equations in Grroud et al. 1994 calculate leakage rate for one defect per 4000 m^2

Abbreviation(s)

gal = US gallons

K + hydraulic conductivity

m = meters

Q_{4000} = leakage rate per 4,000 square meters of liner

Q_{Pond} = leakage rate from entire pond

s = seconds

Attachment 5: Liner Defect Discharge Calculation and Corresponding Alert Level Calculations

Table A5-1
Alert Levels - Pregnant Leach Solution Pond
Rosemont Copper World Project
Pima County, Arizona

Alert Levels 1 and 2 Calculations for Leakage through Primary Geomembrane						
Calculation Method[1]	Bernoulli's Equation for Free Discharge Through an Orifice					
$Q = C\,a\,(2\,g\,h_w)^{0.5}$						
a = cross sectional area of orifice (m^2)						
C = coefficient related to the shape of the edges of the hole; for sharp edges, C = 0.6						
g = gravitational acceleration = 9.8 m/s^2						
h_w = hydraulic head at the top of the geomembrane (i.e., depth of water above the geomembrane) (m)						
Q = discharge through the geomembrane hole (m^3/s)						
Facility Information						
Name	Pregnant Leach Solution Pond					
Area	139,500	ft^2	3.2	acres	12,960	m^2
Design Water Depth (h_w)	22	ft			6.7	m
Alert Level 1 Calculations						
Hole Type[1]	Small Hole					
Hole Diameter	2	mm	2.0E-03	m		
Hole Area (a)	3.14	mm^2	3.14E-06	m^2		
Hole Frequency[1] 1 per	4,000	m^2				
Edge Coefficient (C)	0.6	dimensionless				
Leakage Rate per 4,000 m^2	2.16E-05	m^3/s / 4000 m^2				
Leakage Rate for Facility	7.00E-05	m^3/s	1.11	gal/min	1600	gal/day
Alert Level 2 Calculations						
Hole Type[1]	Standard Hole					
Hole Diameter	11.3	mm	1.1E-02	m		
Hole Area (a)	100	mm^2	1.00E-04	m^2		
Hole Frequency[1] 1 per	4,000	m^2				
Edge Coefficient (C)	0.6	dimensionless				
Leakage Rate per 4,000 m^2	6.88E-04	m^3/s / 4000 m^2				
Leakage Rate for Facility	2.23E-03	m^3/s	35	gal/min	50,900	gal/day
Summary						
Alert Level 1	7.00E-05	m^3/s	1.1	gal/min	1,600	gal/day
Alert Level 2	2.23E-03	m^3/s	35	gal/min	50,900	gal/day

Table A5-1

Alert Levels - Pregnant Leach Solution Pond

Rosemont Copper World Project

Pima County, Arizona

Notes

1. US EPA, 1987. *Background Document on Proposed Liner and Leak Detection Rule.* United States Environmental Protection Agency, EPA 530 SW 87 015, May.

Abbreviation(s)

a = cross sectional area of orifice (m^2)

C = coefficient related to the shape of the edges of the hole; for sharp edges, C = 0.6 (dimensionless)

ft = foot or feet

ft^2 = square feet

g = gravitational acceleration = 9.8 m/s^2

gal = US gallons

h_w = hydraulic head at the top of the geomembrane (i.e., depth of water above the geomembrane) (m)

m = meter or meters

m^2 = square meters

min = minutes

Q = discharge through the geomembrane hole (m^3/s)

s = seconds

Conversion Factors

1	acre	=	43,560	ft^2
1	ft	=	0.3048	m
1	ft^2	=	0.0929	m^2
1	gal	=	0.0038	m^3
1	min	=	60	s
1	day	=	1,440	min

Table A5-2

Alert Levels - Primary Settling Pond - Solution Pond

Rosemont Copper World Project

Pima County, Arizona

Alert Levels 1 and 2 Calculations for Leakage through Primary Geomembrane						
Calculation Method[1]	Bernoulli's Equation for Free Discharge Through an Orifice					
$Q = C\, a\, (2\, g\, h_w)^{0.5}$						
a = cross sectional area of orifice (m^2)						
C = coefficient related to the shape of the edges of the hole; for sharp edges, C = 0.6						
g = gravitational acceleration = 9.8 m/s^2						
h_w = hydraulic head at the top of the geomembrane (i.e., depth of water above the geomembrane) (m)						
Q = discharge through the geomembrane hole (m^3/s)						
Facility Information						
Name	Primary Settling Pond - Solution					
Area	160,000	ft^2	3.7	acres	14,864	m^2
Design Water Depth (h_w)	18	ft			5.5	m
Alert Level 1 Calculations						
Hole Type[1]	Small Hole					
Hole Diameter	2	mm	2.0E-03	m		
Hole Area (a)	3.14	mm^2	3.14E-06	m^2		
Hole Frequency[1] 1 per	4,000	m^2				
Edge Coefficient (C)	0.6	dimensionless				
Leakage Rate per 4,000 m^2	1.95E-05	m^3/s / 4000 m^2				
Leakage Rate for Facility	7.26E-05	m^3/s	1.15	gal/min	1,660	gal/day
Alert Level 2 Calculations						
Hole Type[1]	Standard Hole					
Hole Diameter	11.3	mm	1.1E-02	m		
Hole Area (a)	100	mm^2	1.00E-04	m^2		
Hole Frequency[1] 1 per	4,000	m^2				
Edge Coefficient (C)	0.6	dimensionless				
Leakage Rate per 4,000 m^2	6.22E-04	m^3/s / 4000 m^2				
Leakage Rate for Facility	2.31E-03	m^3/s	37	gal/min	52,800	gal/day
Summary						
Alert Level 1	7.26E-05	m^3/s	1.15	gal/min	1,660	gal/day
Alert Level 2	2.31E-03	m^3/s	37	gal/min	52,800	gal/day

Table A5-2
Alert Levels - Primary Settling Pond - Solution Pond
Rosemont Copper World Project
Pima County, Arizona

Notes
1. US EPA, 1987. *Background Document on Proposed Liner and Leak Detection Rule.* United States Environmental Protection Agency, EPA 530 SW 87 015, May.

Abbreviation(s)
a = cross sectional area of orifice (m^2)
C = coefficient related to the shape of the edges of the hole; for sharp edges, C = 0.6 (dimensionless)
ft = foot or feet
ft^2 = square feet
g = gravitational acceleration = 9.8 m/s^2
gal = US gallons
h_w = hydraulic head at the top of the geomembrane (i.e., depth of water above the geomembrane) (m)
m = meter or meters
m^2 = square meters
min = minutes
Q = discharge through the geomembrane hole (m^3/s)
s = seconds

Conversion Factors

1	acre	=	43,560	ft^2
1	ft	=	0.3048	m
1	ft^2	=	0.0929	m^2
1	gal	=	0.0038	m^3
1	min	=	60	s
1	day	=	1,440	min

Table A5-3

Alert Levels - Primary Settling Pond - Thickener Pond

Rosemont Copper World Project

Pima County, Arizona

Alert Levels 1 and 2 Calculations for Leakage through Primary Geomembrane						
Calculation Method[1]	Bernoulli's Equation for Free Discharge Through an Orifice					
$Q = C\,a\,(2\,g\,h_w)^{0.5}$						
a = cross sectional area of orifice (m^2)						
C = coefficient related to the shape of the edges of the hole; for sharp edges, C = 0.6						
g = gravitational acceleration = 9.8 m/s^2						
h_w = hydraulic head at the top of the geomembrane (i.e., depth of water above the geomembrane) (m)						
Q = discharge through the geomembrane hole (m^3/s)						
Facility Information						
Name	Primary Settling Pond - Thickener					
Area	60,000	ft^2	1.4	acres	5,574	m^2
Design Water Depth (h_w)	10	ft			3.0	m
Alert Level 1 Calculations						
Hole Type[1]	Small Hole					
Hole Diameter	2	mm	2.0E-03	m		
Hole Area (a)	3.14	mm^2	3.14E-06	m^2		
Hole Frequency[1] 1 per	4,000	m^2				
Edge Coefficient (C)	0.6	dimensionless				
Leakage Rate per 4,000 m^2	1.46E-05	m^3/s / 4000 m^2				
Leakage Rate for Facility	2.03E-05	m^3/s	0.32	gal/min	460	gal/day
Alert Level 2 Calculations						
Hole Type[1]	Standard Hole					
Hole Diameter	11.3	mm	1.1E-02	m		
Hole Area (a)	100	mm^2	1.00E-04	m^2		
Hole Frequency[1] 1 per	4,000	m^2				
Edge Coefficient (C)	0.6	dimensionless				
Leakage Rate per 4,000 m^2	4.64E-04	m^3/s / 4000 m^2				
Leakage Rate for Facility	6.46E-04	m^3/s	10	gal/min	14,800	gal/day
Summary						
Alert Level 1	2.03E-05	m^3/s	0.32	gal/min	460	gal/day
Alert Level 2	6.46E-04	m^3/s	10	gal/min	14,800	gal/day

Table A5-3
Alert Levels - Primary Settling Pond - Thickener Pond
Rosemont Copper World Project
Pima County, Arizona

Notes

1. US EPA, 1987. *Background Document on Proposed Liner and Leak Detection Rule.* United States Environmental Protection Agency, EPA 530 SW 87 015, May.

Abbreviation(s)

a = cross sectional area of orifice (m^2)
C = coefficient related to the shape of the edges of the hole; for sharp edges, C = 0.6 (dimensionless)
ft = foot or feet
ft^2 = square feet
g = gravitational acceleration = 9.8 m/s^2
gal = US gallons
h_w = hydraulic head at the top of the geomembrane (i.e., depth of water above the geomembrane) (m)
m = meter or meters
m^2 = square meters
min = minutes
Q = discharge through the geomembrane hole (m^3/s)
s = seconds

Conversion Factors

1	acre	=	43,560	ft^2
1	ft	=	0.3048	m
1	ft^2	=	0.0929	m^2
1	gal	=	0.0038	m^3
1	min	=	60	s
1	day	=	1,440	min

Table A5-4
Alert Levels - Raffinate Pond
Rosemont Copper World Project
Pima County, Arizona

Alert Levels 1 and 2 Calculations for Leakage through Primary Geomembrane						
Calculation Method[1]	Bernoulli's Equation for Free Discharge Through an Orifice					
$Q = C\, a\, (2\, g\, h_w)^{0.5}$						
a = cross sectional area of orifice (m^2)						
C = coefficient related to the shape of the edges of the hole; for sharp edges, C = 0.6						
g = gravitational acceleration = 9.8 m/s^2						
h_w = hydraulic head at the top of the geomembrane (i.e., depth of water above the geomembrane) (m)						
Q = discharge through the geomembrane hole (m^3/s)						
Facility Information						
Name	Raffinate Pond					
Area	65,400	ft^2	1.5	acres	6,076	m^2
Design Water Depth (h_w)	22	ft			6.7	m
Alert Level 1 Calculations						
Hole Type[1]	Small Hole					
Hole Diameter	2	mm	2.0E-03	m		
Hole Area (a)	3.14	mm^2	3.14E-06	m^2		
Hole Frequency[1] 1 per	4,000	m^2				
Edge Coefficient (C)	0.6	dimensionless				
Leakage Rate per 4,000 m^2	2.16E-05	m^3/s / 4000 m^2				
Leakage Rate for Facility	3.28E-05	m^3/s	0.52	gal/min	750	gal/day
Alert Level 2 Calculations						
Hole Type[1]	Standard Hole					
Hole Diameter	11.3	mm	1.1E-02	m		
Hole Area (a)	100	mm^2	1.00E-04	m^2		
Hole Frequency[1] 1 per	4,000	m^2				
Edge Coefficient (C)	0.6	dimensionless				
Leakage Rate per 4,000 m^2	6.88E-04	m^3/s / 4000 m^2				
Leakage Rate for Facility	1.04E-03	m^3/s	17	gal/min	23,800	gal/day
Summary						
Alert Level 1	3.28E-05	m^3/s	0.52	gal/min	750	gal/day
Alert Level 2	1.04E-03	m^3/s	17	gal/min	23,800	gal/day

Table A5-4
Alert Levels - Raffinate Pond
Rosemont Copper World Project
Pima County, Arizona

Notes

1. US EPA, 1987. *Background Document on Proposed Liner and Leak Detection Rule.* United States Environmental Protection Agency, EPA 530 SW 87 015, May.

Abbreviation(s)

a = cross sectional area of orifice (m^2)
C = coefficient related to the shape of the edges of the hole; for sharp edges, C = 0.6 (dimensionless)
ft = foot or feet
ft^2 = square feet
g = gravitational acceleration = 9.8 m/s^2
gal = US gallons
h_w = hydraulic head at the top of the geomembrane (i.e., depth of water above the geomembrane) (m)
m = meter or meters
m^2 = square meters
min = minutes
Q = discharge through the geomembrane hole (m^3/s)
s = seconds

Conversion Factors

1	acre	=	43,560	ft^2
1	ft	=	0.3048	m
1	ft^2	=	0.0929	m^2
1	gal	=	0.0038	m^3
1	min	=	60	s
1	day	=	1,440	min

Table A5-5
Alert Levels - Reclaim Pond
Rosemont Copper World Project
Pima County, Arizona

Alert Levels 1 and 2 Calculations for Leakage through Primary Geomembrane						
Calculation Method[1]	Bernoulli's Equation for Free Discharge Through an Orifice					
$Q = C\,a\,(2\,g\,h_w)^{0.5}$						
a = cross sectional area of orifice (m^2)						
C = coefficient related to the shape of the edges of the hole; for sharp edges, C = 0.6						
g = gravitational acceleration = 9.8 m/s^2						
h_w = hydraulic head at the top of the geomembrane (i.e., depth of water above the geomembrane) (m)						
Q = discharge through the geomembrane hole (m^3/s)						
Facility Information						
Name	Reclaim Pond					
Area	64,500	ft^2	1.5	acres	5,992	m^2
Design Water Depth (h_w)	22	ft			6.7	m
Alert Level 1 Calculations						
Hole Type[1]	Small Hole					
Hole Diameter	2	mm	2.0E-03	m		
Hole Area (a)	3.14	mm^2	3.14E-06	m^2		
Hole Frequency[1] 1 per	4,000	m^2				
Edge Coefficient (C)	0.6	dimensionless				
Leakage Rate per 4,000 m^2	2.16E-05	m^3/s / 4000 m^2				
Leakage Rate for Facility	3.24E-05	m^3/s	0.51	gal/min	740	gal/day
Alert Level 2 Calculations						
Hole Type[1]	Standard Hole					
Hole Diameter	11.3	mm	1.1E-02	m		
Hole Area (a)	100	mm^2	1.00E-04	m^2		
Hole Frequency[1] 1 per	4,000	m^2				
Edge Coefficient (C)	0.6	dimensionless				
Leakage Rate per 4,000 m^2	6.88E-04	m^3/s / 4000 m^2				
Leakage Rate for Facility	1.03E-03	m^3/s	16	gal/min	23,500	gal/day
Summary						
Alert Level 1	3.24E-05	m^3/s	0.51	gal/min	740	gal/day
Alert Level 2	1.03E-03	m^3/s	16	gal/min	23,500	gal/day

Table A5-5
Alert Levels - Reclaim Pond
Rosemont Copper World Project
Pima County, Arizona

Notes
1. US EPA, 1987. *Background Document on Proposed Liner and Leak Detection Rule.* United States Environmental Protection Agency, EPA 530 SW 87 015, May.

Abbreviation(s)
a = cross sectional area of orifice (m^2)
C = coefficient related to the shape of the edges of the hole; for sharp edges, C = 0.6 (dimensionless)
ft = foot or feet
ft^2 = square feet
g = gravitational acceleration = 9.8 m/s^2
gal = US gallons
h_w = hydraulic head at the top of the geomembrane (i.e., depth of water above the geomembrane) (m)
m = meter or meters
m^2 = square meters
min = minutes
Q = discharge through the geomembrane hole (m^3/s)
s = seconds

Conversion Factors

1	acre	=	43,560	ft^2
1	ft	=	0.3048	m
1	ft^2	=	0.0929	m^2
1	gal	=	0.0038	m^3
1	min	=	60	s
1	day	=	1,440	min

APPENDIX H.2

TSF-1 AND TSF-2 SEEPAGE ANALYSES MEMORANDUM

Technical Memorandum

To: Rosemont Copper Company

From: Wood Environmental and Infrastructure Solutions, Inc. (Wood)

Date: June 24, 2022

Ref: Rosemont Copper World Project – TSF 1 and 2 Seepage Analyses Memorandum

This technical memorandum was prepared by Wood to document the results of the seepage analyses conducted to estimate the amount of seepage that bypasses the seepage collection system within Tailings Storage Facilities (TSFs) 1 and 2 and percolates into the foundation rock. The study was completed to support the Aquifer Protection Permit (APP) Application and Pre-Feasibility Study (PFS) for the Rosemont Copper World Project.

1 Introduction

1.1 Project Description and Purpose

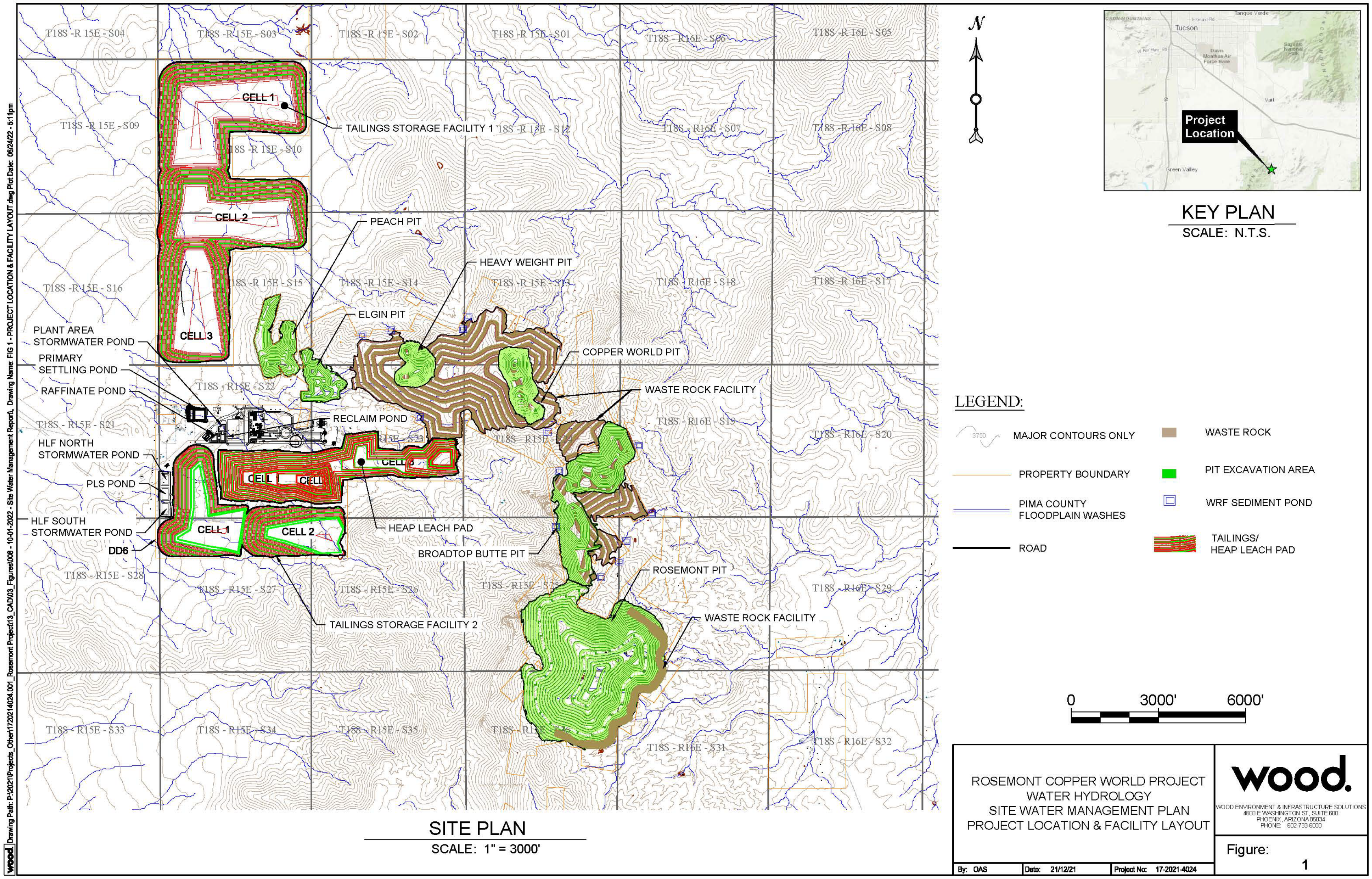
Wood is providing engineering support for the APP Application and PFS for the Rosemont Copper World Project. The proposed Copper World Project will be an open-pit copper mine with associated infrastructure facilities (i.e., heap leach, waste rock dump, conventional tailings storage facilities, etc.) situated within the Santa Rita Mountains in Pima County, Arizona.

The PFS design of tailings storage facilities (TSFs) includes two separate TSFs. TSF-1 is comprised of three separate cells and TSF-2 has two separate cells. Each cell consists of a 50-foot (ft)-high rockfill starter dam and a centerline raise with compacted cyclone sand above the starter dam. Water management within the TSF will consist of a decant pool, seepage collection system (perforated seepage collection piping and seepage collection trenches). Water collected in the decant pool will be pumped back to the processing facility to be reused. Water that seeps out of the tailings would be collected in the seepage collection piping and conveyed to the seepage collection trenches or collected directly by the seepage collection trenches. Because the proposed TSFs are unlined, there is a potential for contact water to bypass the seepage collection system and infiltrate into the bedrock and reach groundwater. To this end, Wood has prepared this technical memorandum to present the results of the seepage analyses conducted to evaluate the performance of the seepage collection system within the TSFs. The objective of this study is to evaluate the performance of the network of seepage collection piping within the TSFs by estimating the amount of seepage that bypasses the seepage collection system and percolates into the underlying foundation soils and geologic formations. The following analysis was conducted as part of this study:

- Steady-state seepage analysis to estimate: (i) the seepage into the foundation rock, and (ii) the flow rate within the alluvial soil near the end of operations for TSFs 1 and 2.

Development of the analyses involved constructing representative cross sections and identifying material parameters for the TSF and subgrade materials. The succeeding sections summarize the methods, geometry, boundary conditions and material properties used to develop the models, as well as the results of the analyses. Figure 1 shows the site layout, including the proposed footprints of TSFs 1 and 2 near the end of operations.

Figure 1 Proposed Facilities Layout Plan



RCC-CW003788

2 Seepage Analyses

The seepage analysis was developed using SLIDE2 Version 2021 (Rocscience, 2021), a commercially available computer program which enables the user to model two-dimensional saturated/unsaturated flow through a porous media. The analyses considered the end of mining when the TSFs are constructed to the proposed final ultimate configurations.

2.1 Assumptions

Key assumptions used in developing the seepage analysis are presented below:

- All materials were assumed to have isotropic homogeneous permeability (Wood, 2022). Details on the selection of the hydraulic conductivity for the TSF materials and foundation soils are provided in Wood (2022).
- All materials were modeled as saturated.
- Effects of seepage from embankments are anticipated to be negligible and are not considered in the two-dimensional model.
- Effects of fractures, faults, and other possible flow paths are assumed to be components of the bulk permeability and are not explicitly modeled.
- Precipitation, infiltration from the ground surface, runoff, and transient flows into the models are not considered.
- The excess pore water pressures (due to consolidation) within the impounded tailings were not considered for this analysis.

2.2 Cross-Section Geometry

Civil layouts of the TSFs were prepared by Wood prior to developing these calculations. The drawings were used to select representative model geometries for the analyses.

The most important aspects of geometry for seepage evaluations are the overall height of the tailings facility, and foundation materials. For the analysis presented in this memorandum, three sections, herein referred to as Sections A, B, and C, were developed to represent the critical sections of TSFs 1 and 2. Figure A1 in Attachment A provides a plan view of the TSF layout showing the locations of selected critical cross sections. The geometries of the cross sections used in this analysis are provided in Figures A2 and A3.

2.3 Boundary Conditions

The boundary conditions (Figure A4) modeled typical seepage conditions anticipated near the end of operations.

- Constant head boundary conditions of El. 3885 ft amsl, 4065, and 4192 ft for TSF-1, and 4344.5 ft for TSF-2 were applied at an offset of 400 ft from the perimeter embankments on the tailings impounded in TSFs 1 and 2, respectively. This represents the assumed maximum phreatic surface condition within the tailings and the tailings beach near the end of mine operations.
- A potential seepage face boundary condition was assigned on the outboard slopes of the perimeter embankments and the base of the slopes.
- To simulate the drainage through horizontal drainage pipes located at the base of the tailings, a zero-pressure boundary condition was applied to the interior face of drains together with a potential seepage face on the exterior surface.

2.4 Material Properties

The TSF geometry consists of five main components: (1) foundation soils, (2) the starter dam, (3) the impounded fine tailings, (4) the drain rock and horizontal drainages pipes, and (5) compacted cyclone sand. According to the *Geotechnical Site Investigation Memorandum Heap Leach, Tailings and Waste Rock Facilities Rosemont Copper World Project* (Wood, 2021), foundation soils within the footprint of the TSFs comprise mostly well graded gravel with notable amounts of sand, silts, and clay at the uppermost layer. Beneath the alluvial soils are weathered rock units. A tabulated summary of the permeability properties selected for different materials are presented in Table 1, along with supporting references for selection of properties.

Table 1 Material Properties Assigned for Seepage Analyses

Material	Permeability (ft/s)	References
Cyclone Sand (Embankment fill and Berm)	3E-4	Assumed Value (Note 1)
Tailings	3E-6	
Starter Dam	2.5E-4	
Horizontal Drainage Pipes	1	
Drain Rock	3.3E-3	
Alluvial Soil	8E-4	Tested Value (Note 2)
Weathered Rock	1.4E-7	Tested Value (Note 3)

Notes: ft/s = feet per second.
1. Wood (2022)
2. Wood (2021)
3. Piteau (2022)

2.5 Discussion of Results

The source of seepage through the foundation materials analyzed in this study are the flows from the applied constant heads due to the tailings pond (i.e., the assumed elevation of the tailings pond near the end of mine operations).

The graphical outputs of the seepage results are presented in Figures A5 through A8 in Attachment A. A summary of the estimated unit fluxes (in $ft^3/d/ft$) that were obtained from the seepage model at the surfaces of the alluvium and the underlying foundation rock are summarized in Table 2 and Table 3, respectively. To obtain an estimate of the seepage through the foundation in each TSF, the unit fluxes were divided by the length of the section and then multiplied by the effective area of each TSF.

The estimated steady-state seepage flow rates that bypass the seepage collection system and percolate into the underlying foundation soils and geologic formations, is approximately 11 and 6.4 gallons per minute (gpm) for TSF 1 and 2, respectively. Based on the flow rates through the alluvial soil shown in Table 2, and weathered rocks shown in Table 3, it is estimated that approximately 2 percent (%) of the gross flow rates through the foundation soils bypass the seepage collection system. This low flow and infiltration rate into the weathered rocks is due to the low hydraulic conductivity of the rock and the preferential pathway through the alluvium into the seepage collection trenches.

Table 2 Estimated Seepage through the alluvial soil (bypass collection system)

TSF	Cross Section	Calc. Discharge/unit length ($ft^3/d/ft$)	Section Length (ft)	Seepage/unit Area ($ft^3/d/ft^2$)	TSF footprint (ft^2)	Estimated Seepage (ft^3/d)	Estimated Bypass Seepage (gpm)
TSF-1	A	13.0	11085	0.001	38,529,104	133,683	694

	B	33.4	5792	0.006			
TSF-2	C	20.7	3787	0.005	13,305,190	72,727	378

*The majority of the seepage through the alluvial soil will be captured in the seepage collection trenches, which will be excavated to bedrock.

Table 3 Estimated Seepage through the weathered rock

TSF	Cross Section	Calc. Discharge/unit length ($ft^3/d/ft$)	Section Length (ft)	Seepage/unit Area ($ft^3/d/ft^2$)	TSF footprint (ft^2)	Estimated Seepage (ft^3/d)	Estimated Seepage (gpm)
TSF-1	A	0.385	11085	3.473E-05	38,529,104	2,116	11.0
	B	0.435	5792	7.510E-05			
TSF-2	C	0.351	3787	9.269E-05	13,305,190	1,233	6.4

3 Summary

The results show that the seepage collection system meets the design intent which is to minimize the amount of seepage percolating into the foundation soils. In summary, the result of the analyses suggests that the amount of seepage that bypasses the seepage collection system and percolates into the foundation soils is less than 2% of the gross flow through the tailings.

It should be noted that the 2D analyses presented in this memorandum is a simplified solution of the 3D flow of contact water into the underlying soils and rocks. The selected cross sections for the seepage analyses is assumed to be representative of TSFs 1 and 2. This assumption ignores topographical features including, but not limited to soil mounds, extent of seepage collection system, etc. These features if present, are expected to influence the results.

4 Limitations

Professional judgments are presented in this memo. These are based partly on the evaluation of technical information gathered, partly on Wood's experience with similar projects, and partly on Wood's understanding of the characteristics of the proposed Rosemont Copper World Project. The findings, interpretations of data, recommendations, professional opinions, and conclusions presented herein are within the limits prescribed by available information at the time the analyses were developed, in accordance with generally accepted professional engineering practice.

In the event of any changes in the nature, design, or characteristics of the project, or if additional data are obtained, the conclusions and recommendations contained herein will need to be re-evaluated by Wood in light of the proposed changes or additional information obtained.

Wood's services were rendered within the limits requested by Rosemont Copper Company with the usual thoroughness and competence of the engineering profession. No other representation, expressed or implied, is included or intended in Wood's proposals, contracts, or reports.

5 References

Rocscience (2021). SLIDE2, 2D limit equilibrium slope stability for soil and rock slopes. 2021 Rocscience Inc, Slope Stability Verification Manual, Toronto, Canada

Piteau (2022) Rosemont Copper World Project, Hydrogeological Characterization, March 2022

Wood (2021), Rosemont Copper World Project – Geotechnical Site Investigation Memorandum Heap Leach, Tailings and Waste Rock Facilities, prepared for Rosemont Copper Company by Wood, December 1.

Wood (2022), Rosemont Copper World Project – Stability Analysis Memorandum Tailings Storage Facilities Rosemont Copper World Project by Wood, January 14.

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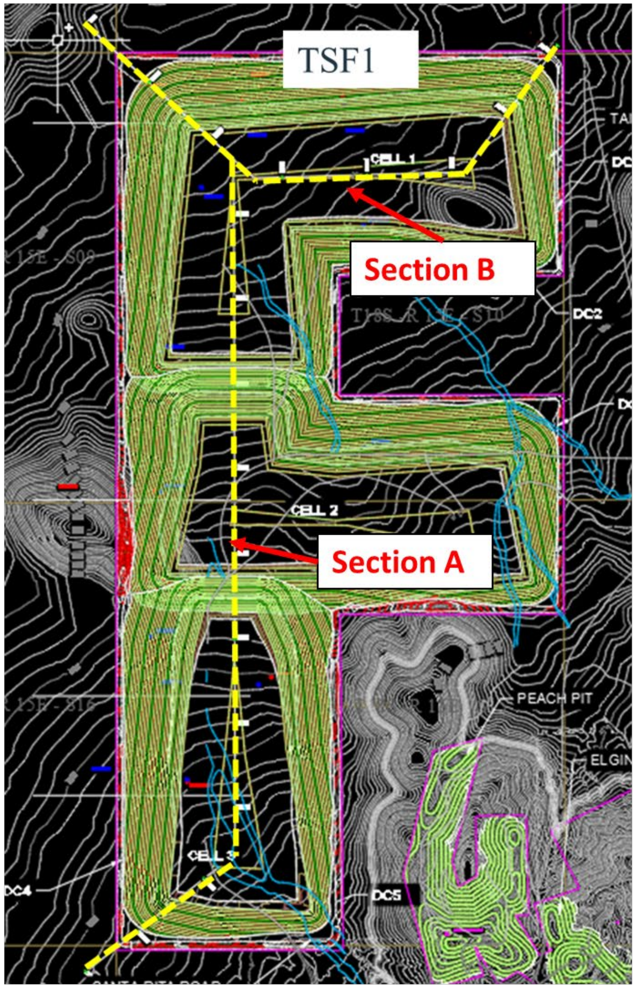
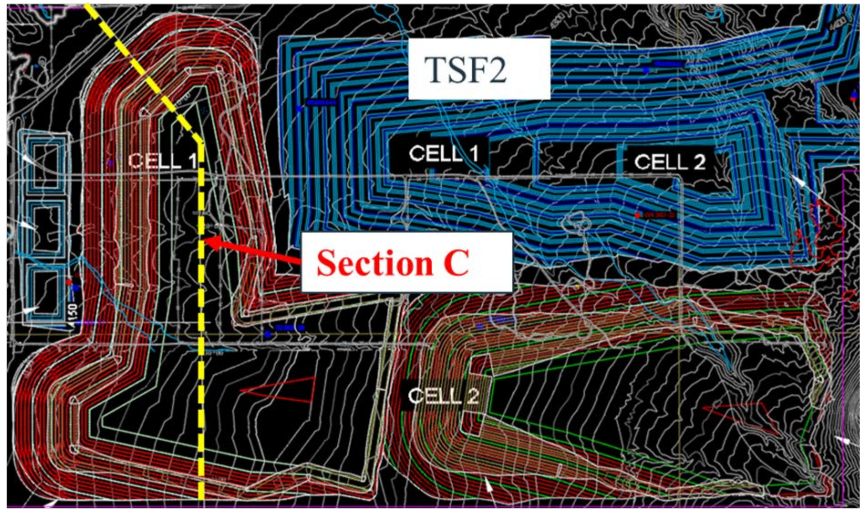
Attachment A

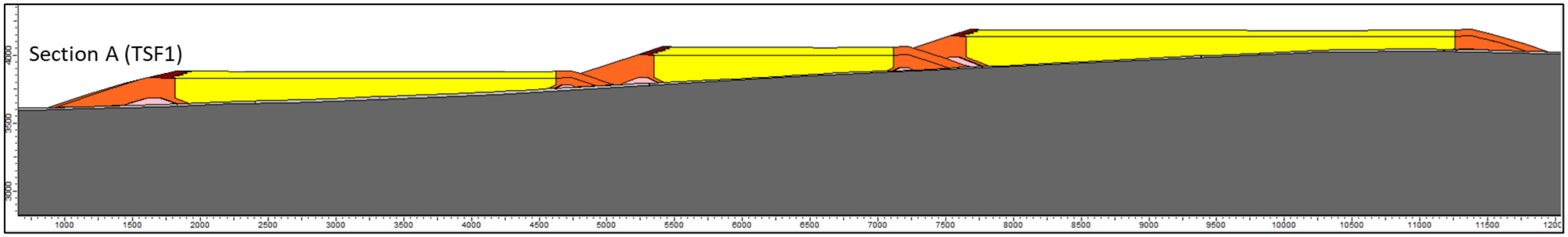


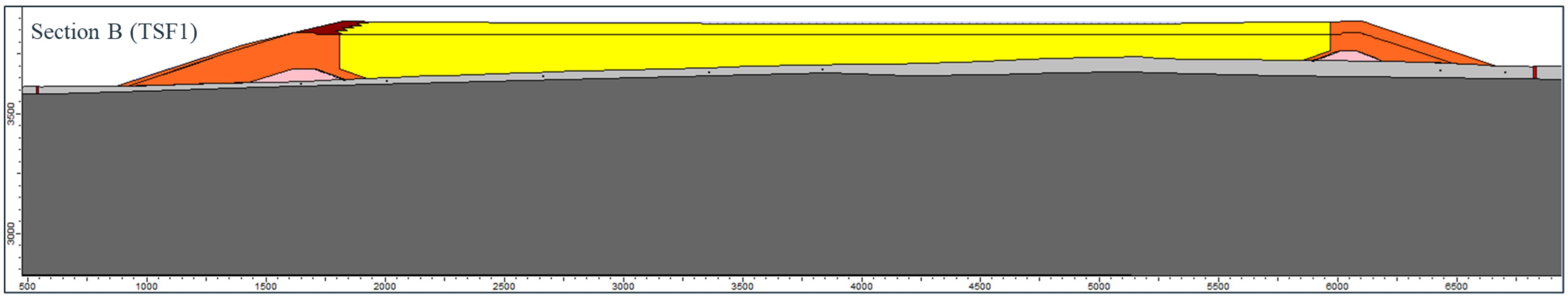
Location of Sections for Seepage Analyses



wood.	TSF 1 and 2 Seepage Analyses Memorandum
	Figure A1
	PROJECT NUMBER: 1720214024
	REV. A

Cross Sections A and B used for seepage analyses on TSF1





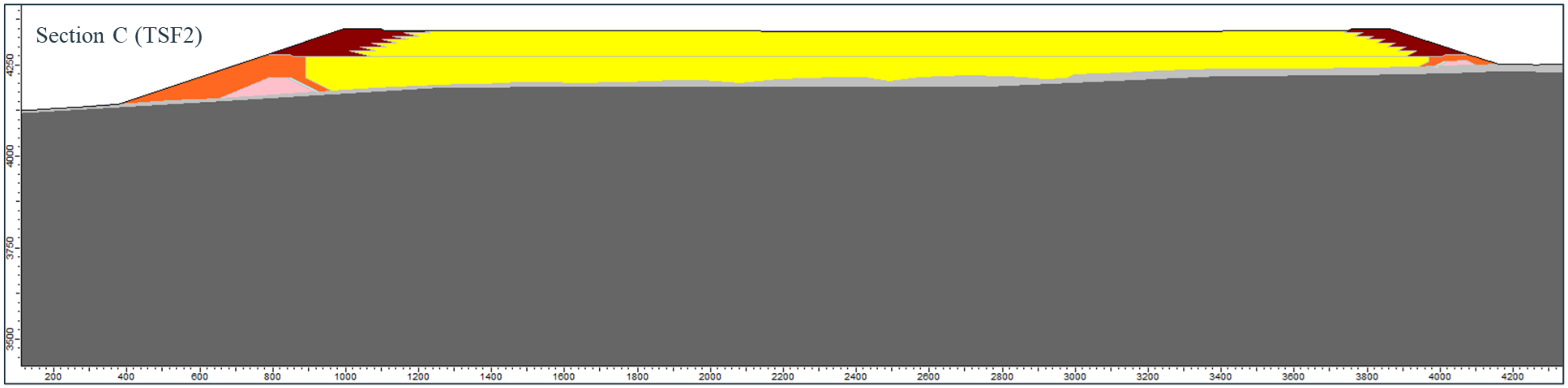
TSF 1 and 2 Seepage Analyses Memorandum

Figure A2

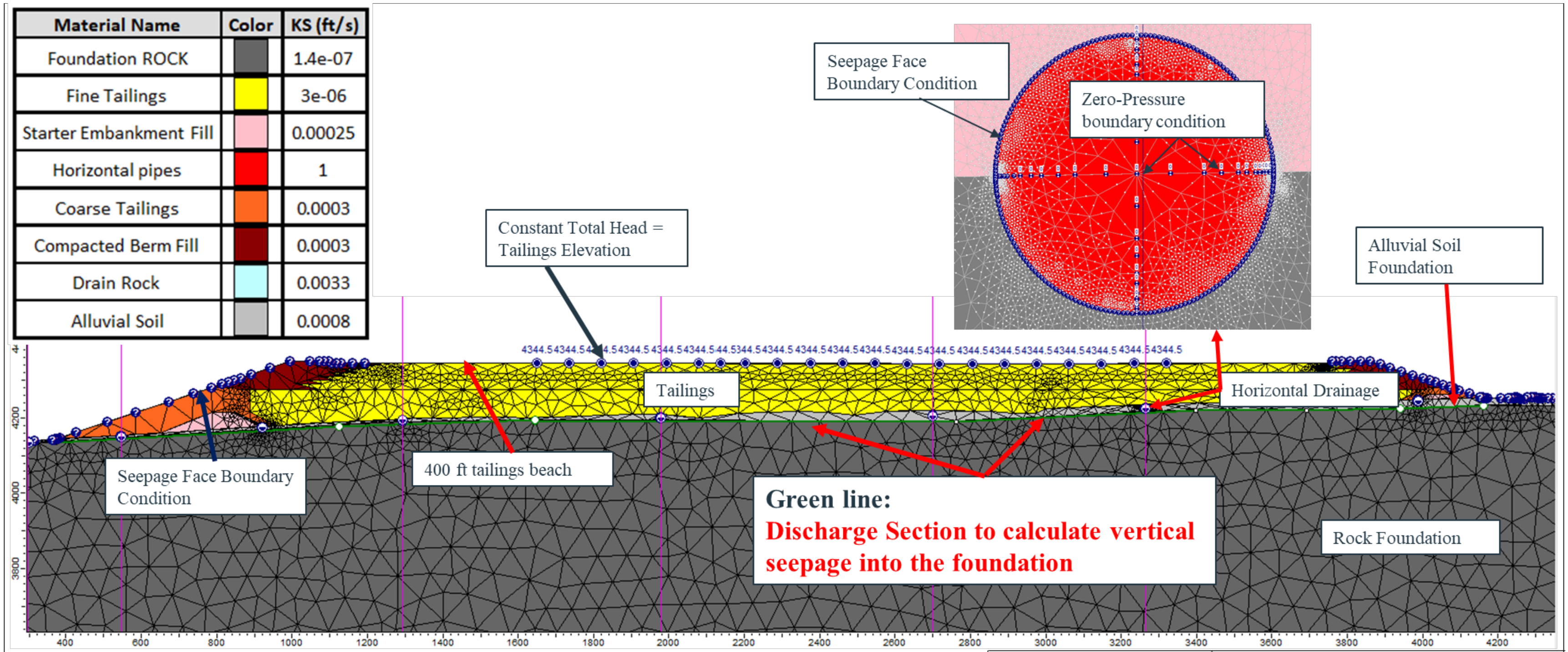
PROJECT NUMBER: 1720214024

REV. A

Cross Sections C used for seepage analyses on TSF2



	TSF 1 and 2 Seepage Analyses Memorandum
	Figure A3
	PROJECT NUMBER: 1720214024
	REV. A



Material Name	Color	KS (ft/s)
Foundation ROCK		1.4e-07
Fine Tailings		3e-06
Starter Embankment Fill		0.00025
Horizontal pipes		1
Coarse Tailings		0.0003
Compacted Berm Fill		0.0003
Drain Rock		0.0033
Alluvial Soil		0.0008

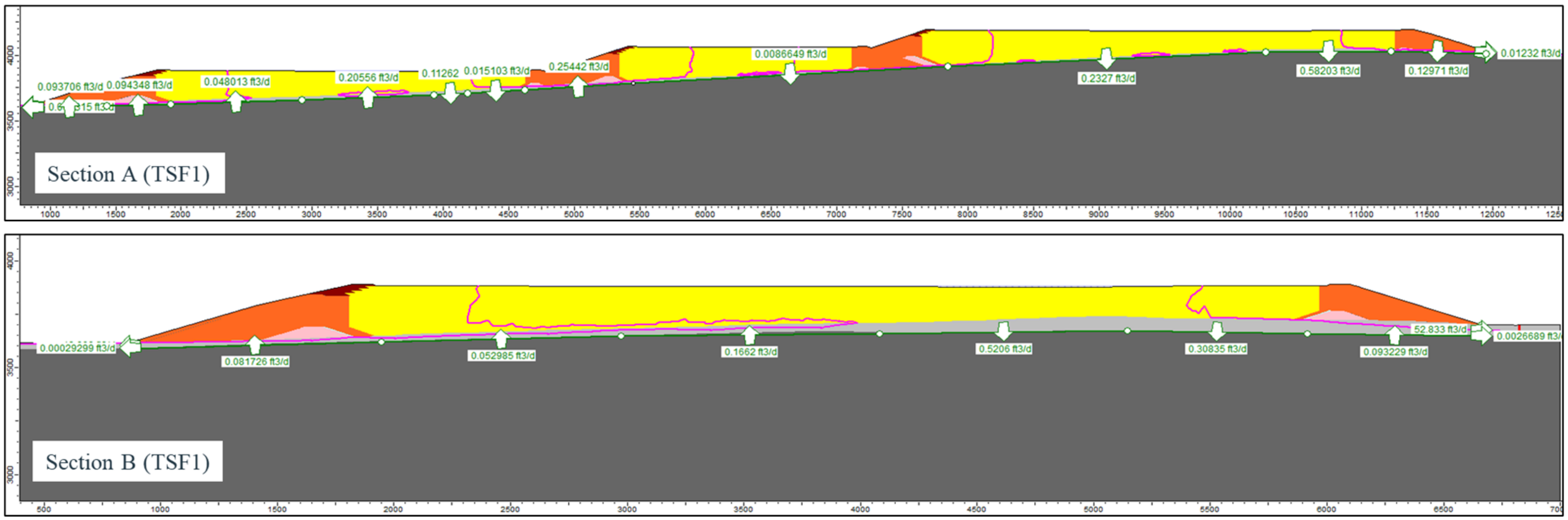
Example of an FEM model (Section C, TSF 2)

TSF 1 and 2 Seepage Analyses Memorandum

Figure A4

PROJECT NUMBER: 1720214024

REV. A



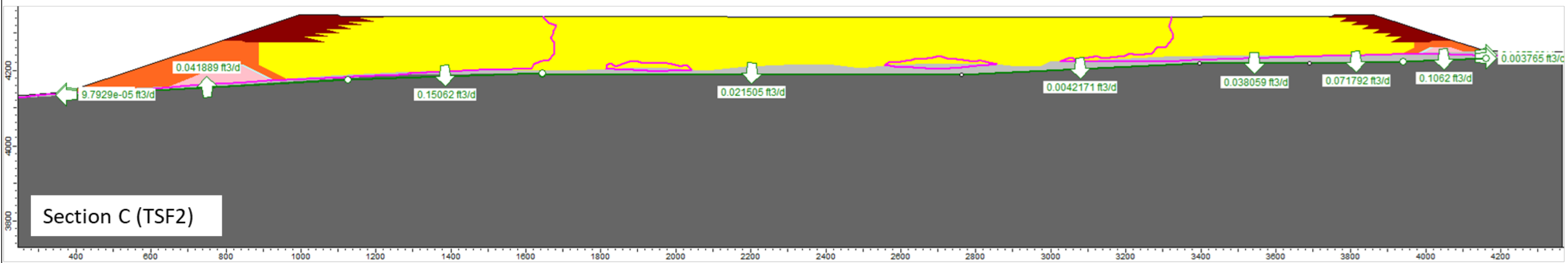
Results of Seepage Analyses on Cross Sections A and B (TSF1): Seepage into the foundation Rock

TSF 1 and 2 Seepage Analyses Memorandum

Figure A5

PROJECT NUMBER: 1720214024

REV. A



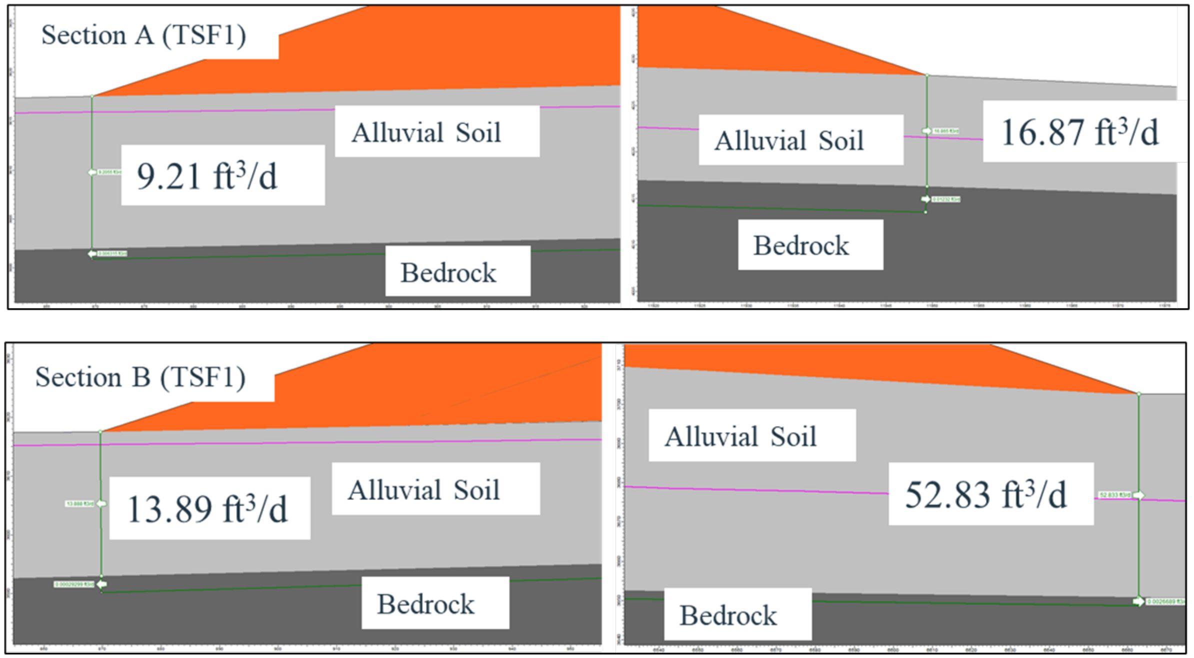
Results of Seepage Analyses on Cross Section C (TSF2): Seepage into the foundation Rock

TSF 1 and 2 Seepage Analyses Memorandum

Figure A6

PROJECT NUMBER: 1720214024

REV. A



Section A (TSF1) Average Seepage: 13.0 ft^3/d

Section B (TSF1) Average Seepage 33.4 ft^3/d

Results of Seepage Analyses on Cross Sections A and B (TSF1): Flow rates through the alluvial soil

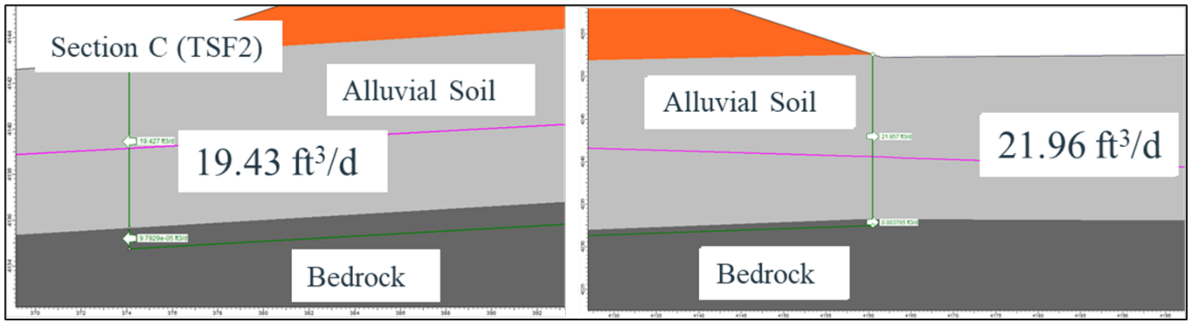
TSF 1 and 2 Seepage Analyses Memorandum

Figure A7

PROJECT NUMBER: 1720214024

REV. A

RCC-CW003800



Section C (TSF2)
Average Seepage
20.7 ft^3/d

Results of Seepage Analyses on Cross Section C (TSF2): Flow rates through the alluvial soil

wood.

TSF 1 and 2 Seepage Analyses
Memorandum

Figure A8

PROJECT NUMBER: 1720214024

REV. A